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Pujak Arora*, Daun Owens**, and Deepak Khazanchi***

Modern businesses face many challenges in today's increasingly complex environment characterized by uncertainty, rapid change, technological innovation and globalization. This necessitates the need for organizations to effectively share and manage knowledge to improve operational efficiency and enhance competitiveness. The ability to leverage knowledge effectively distinguishes a competitive firm from others. The increasing use of virtual projects and teams has presented challenges to effective knowledge sharing. This paper describes a software tool to facilitate knowledge management in virtual projects. Based on previous theoretical and empirical work on the notion of patterns in virtual projects by Khazanchi and Ziggers (2005, and 2008), a tool is developed to support the capturing of such patterns. Following a brief summary of the foundational concepts, the main components of the pattern-based knowledge management tool are described. Also discussed are the ways in which the tool can facilitate knowledge creation and knowledge transfer in virtual projects.

Keywords: Pattern theory, Virtual project, Knowledge management, Pattern-based software tool

Introduction

In an increasingly complex environment, modern businesses face many challenges such as, uncertainty, complexity, change and globalization. This necessitates effective sharing and managing of knowledge by organizations to improve operational efficiency and enhance competitiveness. As such, the knowledge assets of organizations are becoming more valuable than their physical assets. The ability to leverage knowledge effectively now occupies a prominent place among competitive firms, which differentiates them from others (Teece, 1998; and Zach, 1999). This realization has put pressure on organizations to effectively manage and utilize knowledge throughout the organization (Hustad, 2004).

In addition to the need for knowledge management, globalization and decentralization have transformed the way organizations do business in another important way—the increasing use of virtual projects and teams. The distributed nature of virtual teams poses challenges

* MS Student, MIS Department, University of Nebraska at Omaha, 818 Highland, Ridge Ave, Omaha, Nebraska 68182, USA. E-mail: pujakarora@gmail.com
** Ph.D. Scholar, College of Information Science and Technology, University of Nebraska at Omaha, 6001 Dodge Street, PKE 172, Omaha, NE 68182, USA. E-mail: dmowens@unomaha.edu
*** Associate Dean for Academic Affairs, and Professor of Information Systems and Quantitative Analysis, College of Information Science and Technology, University of Nebraska at Omaha, Peter Kiewit Institute of Information Science, Technology and Engineering, 6001 Dodge Street, PKE 172C, Omaha, NE 68182, USA. E-mail: khazanchi@unomaha.edu

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that limit virtual teams from performing as effectively as traditional face-to-face teams (Jarvenpaa and Ives, 1994; and Lipmack and Stamps, 1997). Virtual project teams come together to complete a specific project or task and may leave the team when the project is complete (Khazanchi and Zigurs, 2005). This makes it difficult to learn from experience (Cooke, 2002) and capture and reuse knowledge that an individual develops over time (Grant, 1996).

Communication and knowledge sharing in distributed contexts contribute to the uniqueness of virtual project teams and can provide challenges to virtual project outcomes (e.g., Powell, et al., 2004; Pinsonneault and Caya, 2005; and Corso et al., 2006). Although the elusive nature of knowledge makes the process of storing, processing, and transferring knowledge difficult (May and Taylor, 2003), knowledge sharing across projects can help ensure successful project outcomes (Powell et al., 2004; and Espinosa et al., 2007). All these have put immense pressure on virtual teams and their organizations to devise ways to effectively share knowledge across geographic, temporal, and cultural boundaries.

As a way to facilitate knowledge reuse in virtual project teams, patterns or collections of patterns can be used to communicate and share best practices. The concept of patterns was introduced in the field of architecture by Alexander (Alexander, 1996; and Alexander et al., 1977). The pattern concept has been applied in various areas including computer science (Gamma et al., 1995; Borchers, 2001; and Thomas et al., 2002), management (Austin and Westerman, 2002) and virtual project management (Khazanchi and Zigurs, 2005; and 2008).

Using the idea of patterns, Khazanchi and Zigurs (2005) developed a pattern language to share knowledge and facilitate communication, coordination and control activities within the context of virtual projects. We use the work of Khazanchi and Zigurs (2005; and 2008) as the theoretical foundation for the development of the pattern-based knowledge management software tool described in this paper. We believe that such a tool is unique in its application of pattern-based knowledge management and has the potential of enhancing knowledge management and communication in virtual teams and projects. We describe this software tool and illustrate how it can facilitate knowledge management through capturing, sharing, and managing knowledge about virtual projects in the form of patterns.

Described next is the conceptual background and key concepts that form the basis of the application. This is followed by an overview of the architecture and implementation of the software tool. The paper concludes with a discussion of implications and future work.

Conceptual Background

Knowledge and Knowledge Management

An organization's ability to assemble and exploit knowledge is an effective tool for sustaining a competitive advantage (Teece, 1998; Zach, 1999; Wenger and Snyder, 2000; and May and Taylor, 2003). Knowledge is a mix of experiences, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information (Davenport and Prusak, 1998; and May and Taylor, 2003). People are the ultimate source of knowledge, not databases or templates. In its most basic form, knowledge is "internalized know-how, the ability to tacitly know—in any particular context—what needs
doing and how it should be done" (May and Taylor, 2003, p. 95). This type of knowledge is developed when an individual applies instrumental concepts, interpretations, and assumes contextual relationships to a set of commonly observed phenomena (May and Taylor, 2003). Hence, this type of knowledge is tacit in nature. Tacit knowledge is vital to an organization yet is very difficult and time-consuming to capture (Nonaka and Takeuchi, 1995; and Alav et al., 2006).

Management of tacit knowledge has been identified as a critical aspect in knowledge management. The essence of knowledge management is the firm's ability to combine high value form with experience, context, interpretation, and reflection, and then apply it to decisions and action (Stewart et al., 2000). Thus, knowledge management is defined as the process of acquiring, creating, sharing and using knowledge to achieve organizational objectives (Davenport and Prusak, 1998). Shared knowledge may also be applied in the form of a best practice into a context that reflects the business and the processes of the business (Bock, 1999). The process of knowledge management becomes valuable only when it can sufficiently address the peculiarities of knowledge and application of this knowledge to business processes (Stewart et al., 2000). However, the elusive nature of knowledge makes the process of storing, processing and transferring knowledge difficult (May and Taylor, 2003). Unlike information, knowledge cannot be objectively stored in databases. Additionally, context specific knowledge should maintain its context in all forms (Hustad, 2004). Effective transfer of explicit knowledge depends on a frame of reference as well as a formal coding to maintain accuracy of knowledge (Hustad, 2004). In this paper, we focus on knowledge management as a way to communicate best practices and experiences in virtual project management.

**Virtual Projects and Teams**

In most organizations today, the common unit of Information Technology (IT) work is a project. At any given time, a global organization may have multiple projects carried out simultaneously at many locations. Projects in which “team members are geographically dispersed and rely on information and communication technologies to accomplish work are referred to as virtual projects” (Khaazanchi and Zigurs, 2008). Khaazanchi and Zigurs (2005) identify two important dimensions to classify a virtual project—virtuality and technology. Virtuality is defined as “the extent to which project members are geographically dispersed and rely on information and communication technologies for carrying out project goals” (Khaazanchi and Zigurs, 2005, p. 5). Collaboration technologies are used to overcome virtuality and are therefore defined as “an integrated and flexible set of tools for communicating among project members, structuring process, and supporting task analysis and performance” (Khaazanchi and Zigurs, 2005, p. 6). Team members who complete tasks in a virtual project are geographically distributed. Therefore, we use the term ‘virtual team’ to refer to geographically dispersed team members who rely on technology to accomplish tasks. Virtual team members may also be dispersed on other dimensions such as culture and time, which introduces additional challenges to effective communication in virtual teams (Maznevski and Chudoba, 2000; Massey et al., 2003; and Espinosa et al., 2007).
When applying knowledge management principles in virtual projects, it is important to consider the uniqueness of each project. Projects can differ on several dimensions such as scope, complexity, urgency, and risk (Khazanchi and Zigurs, 2005). In addition, project domain knowledge possessed by experts can differ depending on the type of project and this can affect knowledge sharing across multiple projects. In order to provide a consistent context for effective knowledge sharing it is necessary to classify projects using a common set of project traits. In our knowledge management tool, we adopt the Khazanchi and Zigurs (2005) approach to characterizing projects based on the dimensions of complexity, scope, and risk. Complexity is measured by specific project attributes such as team size, culture, language, gender composition, personal characteristics, and knowledge (Khazanchi and Zigurs, 2005). Scope is measured in terms of project attributes such as duration, innovation, product scope, and multiplicity (Khazanchi and Zigurs, 2005). Risks are broken down into tangible components such as risks associated with programming, technology, engineering, quality, logistics and deployment. The combination of these characteristics affects the effective management of a virtual project. Khazanchi and Zigurs (2005) propose that virtual projects can be classified as follows:

- Lean projects: characterized by low complexity, narrow scope and low risk.
- Hybrid projects: characterized by varying levels of complexity, scope and risk.
- Extreme projects: characterized by high complexity, broad scope and high risk.

This project typology is important for knowledge sharing and the application of patterns. The type of project affects how the project is managed in terms of communication, coordination and the use of collaboration technology. For example, a project manager may encounter unique challenges of communication and coordination in projects characterized by high complexity and high risk. Knowledge in the form of best practices and experiences relating to such challenges will need to be shared with virtual project team members on an ongoing basis. The ideal solution would be to organize such knowledge to classes of problems in a form that can be easily applied to various contexts. As explained later in this paper, patterns provide one effective way to achieve this goal.

Key Factors in Managing Virtual Projects

The distributed nature of virtual teams results in many managerial concerns. Previous research has suggested a number of critical factors or success criteria for the management of virtual projects and teams. In reviewing the literature, three concepts emerge that capture the essence of the issues faced by virtual project teams—communication, coordination, and control (Goodbody, 2005; and Khazanchi and Zigurs, 2005). Communication can be a challenge in virtual environments because facilitation is reliant on various types of information and communications technology. Research in virtual teams has identified various communication-related issues. Issues can arise when there are different interaction styles and preferences (Sarker and Sahay, 2002). Issues also arise due to infrequent communication and perceived lack of responsiveness (Cramton, 2001). In addition, the lack of face-to-face
communication can create problems by inhibiting confidence and trust (Maznevski & Chudoba, 2000; Jarvenpa et al., 2004; and Paul and McDaniel, 2004).

Coordination is the way in which people and technological resources are combined to carry out specific project activities in order to accomplish stated goals (Crowston, 1991; Grant, 1996). Effective coordination is dependent upon many factors such as the degree of virtuality and the nature of the project. Additional factors that may impede coordination that are relevant in a virtual setting include proper team training, team trust, team cohesion (Chinowsky and Rojas, 2003; and Jarvenpa et al., 2004), dependency management (Malk and Crowston, 1994), team and project structure (Gassmann and Von Zedtwitz, 2003), temporal distance (Carmel and Agarwal, 2001; and Espinosa et al., 2007).

Virtual projects require a combination of centralized and decentralized control mechanisms for managing both behaviors and outcomes of project entities. Challenges associated with controlling projects are closely tied to communication and coordination issues. For example, temporal distance makes coordination and control more difficult through its negative effect on communication (Carmel and Agarwal, 2001). Other challenges that affect control virtual projects include reinforcing project objectives (Chinowsky and Rojas, 2003), monitor and measuring issues, collaborative infrastructure (Evans and Munkvold, 2002), and project leadership (Homsy, 2003). Khazanchi and Zigar (2005) describe and organize patterns of effective virtual project management using these key factors impacting the management virtual projects.

Patterns for Knowledge Management

Patterns describe a problem, which occurs over and over again in the environment, and then describes the core of the solution to the problem in such a way that the solution can be used many times without ever doing it the same way twice (Alexander et al., 1977, p. 8).

The renowned architect, Chris Alexander, originally developed patterns as a mechanism for communicating 'good solutions' to recurring classes of problems in architecture. Form, Alexander defines a pattern as a three-part rule that expresses a relationship among a specific context, a problem, and a solution (Alexander et al., 1977). Patterns, according to Alexander, reflect the essential meaning of actual experience that can be abstracted and applied to other contexts. Alexander suggests that we can capture the essential qualities of what we do, then we can apply these qualities to do the same thing in other contexts and applications (Alexander, 1978). Alexander further claims that these 'good qualities' can only be captured by observation, by experience, by both positive and negative examples, and at times, abstract argumentation (Alexander, 1978, pp. 255-259).

Patterns have been used in software engineering to develop 'design patterns' for object-oriented software development (Gamma et al., 1995). Patterns have also been applied in the field of Human Computer Interface Design as a way to offer good examples of user interface designs (Borchers, 2001). Thomas et al. (2002), who worked on a socio-technical part language, used patterns to enable knowledge of the social sciences in the context of Compi
Supported Cooperative Work (CSCW). Finally, Khasanchi and Zigurs (2005) identified patterns for the effective management of virtual projects. The latter forms the basis for the knowledge management software tool discussed in this paper.

A Pattern Language for Virtual Projects

Pattern languages are networks of interrelated patterns or collections of patterns belonging to the same domain (Herrmann et al., 2003). Stated another way, a pattern language is a system of patterns that combine to produce a variety of important outcomes (May and Taylor, 2003). For a pattern language to be useful, it should have several interrelated patterns. Isolated patterns only solve small trivial problems. A set of patterns and interrelationships between them are necessary to provide sufficient comprehensive solutions to non-trivial problems. Developed patterns must provide concrete and tangible solutions to relevant and important problems. It is imperative to develop such patterns to ensure active user involvement. However, emphasis should be on quality rather than on quantity of patterns (Persson et al., 2003).

Khasanchi and Zigurs (2005, and 2008) found that it is possible to identify effective patterns for managing virtual projects and based their patterns on the three key factors that are fundamental to managing virtual projects—communication, coordination and control. Generation of a pattern language from the combination of these characteristics of virtual projects becomes an appropriate tool for managing knowledge pertaining to virtual project teams. Therefore, we have used the pattern language developed by Khasanchi and Zigurs as a starting point for expressing knowledge and identifying patterns pertaining to virtual projects in our proposed software tool.

Software Tool for Pattern-Based Knowledge Management in Virtual Projects

Based on the previous theoretical foundations, we believe that patterns provide an effective way to transfer and share knowledge in virtual projects for various reasons. First, patterns are a powerful tool that can overcome the elusiveness of knowledge by encapsulating knowledge and helping to convert tacit knowledge into explicit knowledge (May and Taylor, 2003). Second, patterns are context specific and provide a flexible but structured template to encapsulate knowledge. This facilitates the recipient's ability to correctly process and interpret knowledge on a common frame of reference. Third, individuals can combine patterns in different ways, which open up solutions to different facets of an overall problem (Persson et al., 2003). The applicability of patterns for knowledge management is dependent upon knowledge capture and knowledge communication (May and Taylor, 2003).

Therefore, we have proposed an interactive tool that can be used by virtual project teams to support knowledge creation and sharing via patterns. Our proposed tool, Interactive Pattern Management Tool for Project Management (iPM-T) provides such a framework for the generation and evolution of a pattern language using patterns that have already been defined and validated theoretically by Khasanchi and Zigurs (2005). iPM-T is a web-based tool that supports knowledge transfer and sharing. The tool includes features that support pattern discovery, online collaboration and knowledge sharing for geographically dispersed team members involved in virtual projects. Figure 1 illustrates the architectural basis of the tool.
iPM²T facilitates knowledge creation and transfer by allowing project managers to include new virtual projects in the application, create new patterns, and use existing patterns. Usage of the tool can lead to the evolution of existing patterns, and identification and discovery of new ones. Once identified, the patterns go through an evolutionary cycle of refinement and enhancement based on user interaction. Users have the ability to provide feedback on patterns and offer enhancements based on their use and experience with the pattern. iPM²T also facilitates knowledge sharing. The tool provides support by matching patterns and offering patterns from the pattern repository as a starting point for different virtual project types. Pattern usage within a project is tracked which provides meaningful metrics. Metrics about the use of patterns in a particular project identify common pattern usage and potential project inefficiencies. As such, a project manager or knowledge worker can proactively address these inefficiencies early in the project.

iPM²T consists of three major components—a virtual project repository to allow for characterizing projects into one of the three project types (lean, hybrid or extreme), a pattern repository to facilitate knowledge transfer and sharing, and a metrics repository to capture project and pattern metrics. Each of these three components is further elaborated in the following sections.

**Virtual Project Repository**
The iPM²T project repository interface allows users to enter projects into the system that correspond to real world virtual projects. Once entered into the repository, the tool provides project managers the ability to classify the project into one of the three project types—lean,
hybrid, or extreme. This classification is helpful when applying existing patterns to a project. Active and inactive projects are stored in the repository to allow for real-time management as well as past project history. Project managers use a dashboard in the tool to view all of their active projects. Figure 2 provides an example of the project dashboard available to project managers. Here, iPM'T displays projects entered by the project manager along with the date created and a brief description.

Figure 2: Virtual Project Repository

Upon entering a new project, iPM'T offers a predefined set of multiple-choice questions targeted to extract specific information about the project relating to complexity, scope, risk, virtuality, and project success. The questions are aggregated together to assess each of these concepts. For detailed background on the basis of these metrics, the reader is required to refer to Appendix and Khazanchi and Zigurs (2005). Based on selected answers for each construct, the tool visually displays ratings on a scale of 1 to 5. The user can expand a particular category and see responses to each of the questions in that category. Once all questions relating to these concepts have been answered, the tool automatically categorizes the virtual project as lean, hybrid, or extreme. Based on this information, iPM'T then can suggest patterns that are applicable to a virtual project based on its type. Figure 3 shows an example, the different metrics necessary for 'ERP Implementation' project. This project is categorized by the system as a 'hybrid' project based on the responses provided. A score is displayed for each of the five major categories (complexity, scope, risk, virtuality, and success) that are used to determine the project classification.

Pattern Repository

iPM'T houses a repository of all the patterns that have been entered into the system and which form the basis for the virtual project management pattern language. Knowledge sharing
is supported with the pattern repository, which can be used to suggest patterns for various projects and scenarios. The pattern repository (shown in Figure 4) facilitates knowledge...
transfer and sharing by making patterns available to users in a standard format. Users can search for a specific pattern or browse a list of all patterns based on pattern name or project typology. A project manager can reuse an existing pattern in its original form or modify it according to the specific context. If a user modifies a pattern, the modification becomes a new pattern; however, the new pattern is linked to the original pattern using a Wiki-based feature.

As discussed earlier, due to their nature, stored patterns conform to a three-part structure that includes a context, solution and associated problem. IPM3T provides a common interface for storing knowledge in this three-part structure. Project managers can browse the pattern repository and gather knowledge on specific problems and solutions.

New knowledge is stored in the structure of a pattern. Users enter new patterns and edit existing patterns using a single form. The form allows users to create, edit, discuss/comment and rate specific patterns. The form requires users to associate a pattern with a particular project type—lean, hybrid, or extreme. This assures that each pattern has an appropriate context. The discussion and rating tools offer ways for virtual project team members to collaborate on the effectiveness of a particular pattern. Team members can also provide comments on how specific patterns are combined together to produce a specific outcome. As stated earlier, patterns have been shown to be most useful when combined together to produce specific outcomes. Figure 5 shows the simple interface for creating and continually updating patterns.

Figure 5: Interface for Creating and Editing Patterns
Metrics Repository
The third and final component of iPM²T is the Metrics Repository, which offers the ability to provide important metrics regarding the use of patterns in various projects throughout the organization. First, the metrics repository can provide management with insight into the different types of projects undertaken by the organization by providing information about the total number of active and inactive projects in each of the three categories. Managers can also view the distribution of specific patterns throughout various projects. The ability to track pattern usage can be helpful in identifying potential problem areas. For example, the high occurrence of a pattern such as 'FaceTime' may indicate potential conflicts and inefficiencies in particular project teams since the pattern reflects conflicts between team members. A widespread occurrence of the 'FaceTime' pattern in different projects can indicate an inherent problem in the organization, possibly in the organization culture. As such recognizing the high occurrence of the pattern can assist upper management in dealing with the problem. Figure 6 provides an example of how the tool can capture metrics at the pattern level.

Example of iPM²T in Practice
iPM²T offers a web-based, easy-to-use interface that supports a project starting with project initiation all the way through to project closing. Starting from project initiation, a project manager creates the new project in iPM²T. Once a project has been entered, the project manager can quickly share important information about the project characteristics with virtual team members. Throughout the planning, executing, monitoring and controlling phases of the project, the project manager has the ability to call upon the knowledge of others by tapping into the pattern repository. The project manager can search for patterns that apply to the specific project type or search for patterns that apply to a particular problem.
Throughout this process, the project manager is encouraged to create new patterns and update existing patterns to facilitate knowledge sharing. A simplified set of activities, listed below, describes how a project manager would typically interact with the tool.

- A project manager enters a new virtual project into the project repository and answers questions relating to the project. Based on selected responses, the tool classifies the project as lean, hybrid or extreme type.
- Next, the project manager taps into the pattern repository, which provides a list of suggested patterns as a starting point for knowledge sharing in the project.
- The project manager chooses which patterns they may want to implement in the project.
- As the project-lifecycle progresses, the project manager discovers new patterns and offers modifications to existing patterns.
- The project manager or team members link together patterns that produce specific outcomes using the wiki feature.
- The project manager interacts with iPM²T and updates the tool with information based on their experience in the project.
- Management accesses the metrics repository for information about recently used patterns, highly used patterns, and various project types. This information can be used to make decisions about new projects and address potential problems throughout the organization.

iPM²T supports knowledge sharing through continuous interaction among project managers. Knowledge management is effective when project managers actively contribute, collaborate, and transfer important knowledge gained from personal experiences.

Conclusion

Patterns offer a unique way of managing knowledge. In this paper, we have introduced a unique tool, iPM²T that facilitates knowledge transfer and creation in the domain of virtual project management. Project managers, project teams and higher management are the primary users of the tool. Project managers can create projects and iPM²T assists in identifying applicable patterns for their projects. Managers can also contribute to the pattern repository by updating patterns so that the patterns are continually refined and improved over time. With active usage of the tool, managers and project managers can develop new patterns as they encounter new challenges and solutions. As a result, knowledge becomes explicit, documented and shared within the organization. Ultimately, the entire pattern language would evolve, becoming more beneficial to the organization and an active way to manage project knowledge.

iPM²T was originally developed as a prototype to test the ability to capture and reuse patterns. The next phase of this research is to perform an empirical study to capture data on the usability and applicability of the tool for knowledge sharing. Based on results of the study, we hope to enhance iPM²T. 

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