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Using Digital Tabletops to Support Agile Project Planning

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Using Digital Tabletop to Support Agile Project Planning" submitted by XIN WANG in partial fulfillment of the requirements of the degree of Master of Science.

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Abstract

Digital tabletops are a cutting-edge technology for group collaborations. However, they are rarely used to support agile planning meetings - a typical group activity for agile software teams. In this thesis, I describe an exploration of using digital tabletops in agile project planning. I first review existing agile planning tools and analyze limitations that can be overcome by tabletops. Then I illustrate APDT – a tabletop based tool to support agile planning meetings. The evaluations of APDT are provided. They concentrate on the use of tabletops for both co-located and distributed environments. The co-located evaluation exposes some changes of user behavior when using a tabletop and APDT. It also shows several usability problems that should be (and were) removed from APDT design. The distributed study highlights whether it is applicable to use a tabletop for distributed agile planning meetings and how a meeting is supported by a distributed tabletop solution. The studies reveal that current tabletops are sufficient in a distributed agile planning context. To support this statement, I observed the user behavior within co-located and distributed agile planning meetings. I also assess the results of agile planning meetings, the use of territory and orientation, as well as the group collaborations within a distributed setting. My experiments use a real-world application scenario and show that even given the limitations of commercial or near-commercial digital tabletops, their use is beneficial for distributed agile project planning.

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Publications from This Thesis

Some of the materials and ideas presented in this thesis may have previously appeared in the following peer reviewed publications:

Ghanam, Y., Wang, X., & Maurer, F. (2008). Utilizing Digital Tabletops in Co-located Agile Planning Meetings. *Proceeding of Agile Conference 2008* (pp. 51-62). Toronto: IEEE Press.

Wang, X., & Maurer, F. (2008). Tabletop AgilePlanner: A Tabletop-based Project Planning Tool for Agile Software Development Teams. *Proceeding of the 3rd IEEE Tabletop and Interactive Surface* (pp. 129-136). Amsterdam: IEEE Press.

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List of Symbols, Abbreviations and Nomenclature

Symbol	Definition
DAP	Distributed Agile Planner
UI	User Interface
APDT	Agile Planner for Digital Tabletop
WIMP	Window Icon Menu Pointing device
DViT	Digital Vision Touch
SDK	Software Development Kit
FTIR	Frustrated Total Internal Reflection
WPF	Windows Presentation Foundation
VOIP	Voice Over Internet Protocol
MPG	Mixed Presence Groupware

CHAPTER 1: INTRODUCTION

Agile development is a flexible software development process. It uses a set of lightweight techniques (coming from extreme programming or scrum) to manage software development and to guarantee fast responds to user requirements. Agile development highlights collaborations between software developers and customers. In an agile team, one medium of communicating developers with customers are *story cards*. A story card is often used to record *user stories*, which is one or two sentences describing user requirements formulated in the business language of users. For example, a user story could be:

> As a customer representative, I can search for my customers by their first and last name. [User Story]

Agile planning is a story card-centered process. Agile development's main task is to produce deliverables that keep integrating the newest update of user requirements. To fulfill this goal, customers iteratively create story cards for presenting their needs. Agile developers work on the cards and implement them in a reasonable time frame.

In order to catch up with the new customer requirements, agile development is iteratively organized (see Figure 1-1). It consists of several short-term (normally one or two week) phases, which are named "*iterations*". An iteration has a fixed time frame, a set of story cards that should be completed in this time frame, and a group of developers who will work for this iteration.

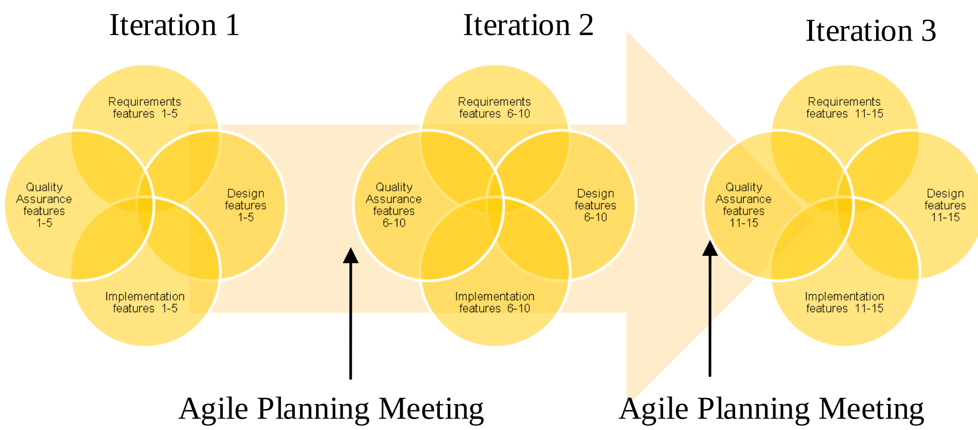

Figure 1-1: Agile development architecture

1.1 Agile Planning Meetings

Project planning is an important activity for agile teams. It keeps a software project running on time and heading to a right direction. In agile software development, project planning is carried out in form of *agile planning meetings*. It is conducted before the start of an iteration. In this meeting, both the software development team as well as the customers is included. They discuss the tasks (mostly the new requirements) that should be completed in the new iteration. Based on the discussions, story cards are created and assigned to the group of developers.

The scale of an agile planning meeting is often determined by the size of an agile team (the number of available developers) and the duration of an iteration. In the Agile Software Engineering Lab, University of Calgary, we have a 5-person student agile team. Observations of their agile planning meetings show that on average, 5 story cards per developer is an appropriate amount within a two-week iteration. Informal observations in industry with teams of similar size indicate the same ballpark of story cards: 20-50 cards per iteration.

1.1.1The Scenario of Co-located Agile Planning Meeting

Agile planning meetings are usually conducted in a co-located environment. Collaborators sit around a physical table, use face-to-face conversations to drive project development (see Figure 1-2). Paper index cards are the main artifacts in agile planning meetings. An index card represents a task that takes some time and effort to complete. From the other side, it is an informal contract that requires software developers to strive to finish within an estimated time frame. A paper index card often shows the name of a task, the owner of the card, the estimated effort to complete, (later) actual hours, and a short task description.

Figure 1-2: Pen-paper based meeting with paper index card

Co-located agile planning meetings rely on verbal conversations and card operations. Meeting participants often grab cards, use pens to edit card, trash obsolete cards and pass cards. Cards are often rotated and moved. Rotating index cards aims at improving the card's readability for specific participants. Ownership of a card is also indicated when participants rotate their "reserved" cards to fit their seat orientation. Moving an index card is another tiny but critical operation. To set up ownership, collaborators move cards into their own “reserved” territories on a table. Sometimes, moving cards is to rank them so that the priority of tasks is displayed.

Pen and paper-based agile planning meetings are inexpensive and easy to operate. My observations indicate that participants feel comfortable to operate paper cards and use face-to-face conversation to discuss upcoming tasks. However, some drawbacks are also observed. For example, agile development is an iterative process. An agile planning meeting often starts from reviewing the cards created on last meeting. Before a planning meeting, cards from last meeting must be carefully placed on table surface. The position of the cards is also important because it represents the priority of tasks. Moreover, to effectively manage and share index cards, agile teams often post their cards on websites. Extra effort must be made to convert a paper card into an electronic version.

1.1.2 The Scenario of Distributed Agile Planning Meeting

Software development is moving to a distributed environment [Karolak, 1998], thus calling for an increasing number of distributed agile planning meetings. The geographically separated environment destroys the basis of co-located collaboration. Co-located pen-paper based agile planning meetings are no more applicable to distributed agile teams. To overcome the barriers of distributed communications, agile teams turn to rely on electronic devices, such as projectors, computers and software such as project planning applications to support distributed agile planning meetings.

Morgan [Morgan, 2008] described a scenario that developers at two sites use teleconference and paper index cards to conduct distributed agile planning meeting. The participants use speakerphones to discuss the future development, and replicate paper index cards at both sites to maintain an identical understanding. Morgan's observations indicate that mistakes often occurred in this meeting. At the end of the distributed meeting, sometimes "both sides do not even have the same number of story cards".

Some project planning tools are used to help distributed agile planning meetings. I observed a scenario where researchers from the ASE lab did project planning with their partners from Colorado, US. They used a projector to display a PC screen and both sides (Calgary and Colorado) shared the interface of an agile planning tool-Distributed Agile Planner [Morgan & Maurer, 2004]. A speakerphone was used for verbal communications.

This scenario shows the advantages of using project planning tools to support distributed agile planning meetings. At the end of the meeting, both sides share the same cards, which resolved the card inconsistency in paper card-based agile planning meetings. The cards are automatically saved in a server for the following meetings.

However, I also observed that concurrent interactions were hindered within the distributed teams. In a paper-card based meeting, most participants feel free to concurrently operate story cards. Nevertheless, the tool-based distributed meeting only allows one or two interactive device (such as mouse and keyboard).. Further, the social interactions between the meeting participants where changed as the looked mostly at the shared display instead of each other.

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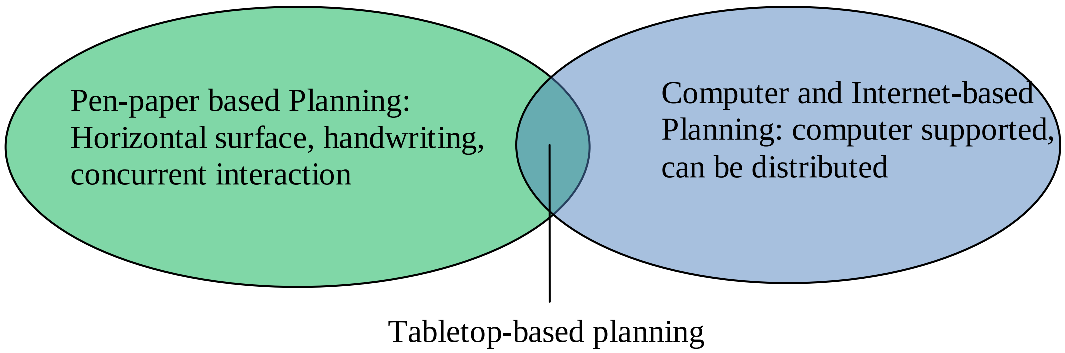

Figure 1-3: Motivation for using digital tabletops

1.2 Thesis Motivation

In trying to solve usability issues of existing tools, I want to find an approach to combine the advantages of physical table-based meeting with computer and Internet-based meeting (see Figure 1-3). Digital tabletops become an applicable solution. A literature review indicated that few attempts were made to utilize digital tabletop technology for agile development. Moreover, the feasibility and utility of using digital tabletops to support co-located and distributed agile project planning remains unknown. Therefore, my thesis strives, first of all, to study the state-of-the-art of digital tabletop and agile planning tools. Secondly, based on the analysis of tabletop and agile project planning, a tabletop-based agile planning tool is developed. This tool will be evaluated in co-located and distributed agile planning meetings. The evaluations concentrate on collecting agile developers' behaviors and exposing their satisfaction of using tabletops for agile planning. The evaluation results will be carefully analyzed to determine the feasibility of using digital tabletop to support agile planning meetings.

1.3 Research Goal

This thesis aims at studying the usage of digital tabletops in agile planning meetings. During this process, the following goals are planned to be fulfilled:

1. Providing an effective tabletop based agile planning tool. This tool is designed to support basic operations of agile planning meetings, such as create/delete story cards, edit cards, and pass around cards. Moreover, the tool should be able to enhance the communications of agile developers by employing the features of digital tabletops.
2. Organizing evaluations to determine the impact of digital tabletops on agile planning meetings. I expect that a digital tabletop facilitates team collaboration in distributed environments. However, to what extends, the collaborations can be improved (or damaged) by digital tabletop, how user behaviors are (positively or negatively) affected are not yet studied.

1.4 Research Constrains

This study is constrained by the hardware devices available and the evaluation participants. Digital tabletops are the hardware platform that will be used for my study. However, there are not many commercial tabletops released. In my lab, there are two off-the-shelf tabletops – one FTIR and one DViT table. They are different in size, screen aspect ratios, the capability of concurrent touches and display resolutions.

Due to a lack of hardware in companies, digital tabletops are not yet applied in real-world agile development. Thus, no industrial agile teams have yet a chance to use tabletops for their agile planning meetings. As a trade-off, student teams are used in my study. They will expose some behaviors of the industrial developer. But they might also affect the evaluation results considering the potential differences between students and the real-world agile practitioners.

1.5 Thesis Structure

This thesis is divided into six chapters:

Chapter 2 reviews present agile planning tools and studies of digital tabletops. In this chapter, I list some major agile planning tools that were used on different platforms. The advantages and shortcomings of using these types of tools are analyzed. Moreover, I investigated current research on digital tabletops. Some important contributions, such as the tabletop hardware design, the study of personal territories on digital tabletop surfaces, the design of distributed tabletops, as well as the comparison of tabletop input mechanisms are briefly described.

Chapter 3 describes my thesis project - AgilePlanner for Digital Tabletop (APDT). APDT is a tabletop based agile planning tool that utilizes digital tabletop technology to support co-located and distributed agile planning meetings. In this chapter, I describe the functions and user interactions of APDT. I also show how I use digital tabletop features to facilitate APDT users. These include the definition of finger gestures, the use of handwriting input and the multi-touch. The hardware to deploy my application is described at the end of this chapter.

Chapter 4 describes the evaluation of the co-located aspect of APDT, including the evaluation goals, participants, contexts and basic methodologies. Moreover, as tabletops and physical tables are all horizontal surface, I will analyze the user behaviors of both agile planning context (tabletop based vs. conventional physical pen-paper based meetings) and find out the differences, the factors that cause the changes and the user preferences.

Chapter 5 focuses on the evaluation of using a tabletop in a distributed agile planning meeting. In this chapter, I will focus on 1. The feasibility of tabletops for supporting distributed tables and 2. The use of some interactive features (personal space, reorientation, inter- and intra- group collaborations) within the distributed agile planning context. The results are listed at the end of this chapter.

Chapter 6 concludes my research, highlights the thesis contributions and suggests possible future work on this research topic.

CHAPTER 2: RELATED WORK

This chapter provides a discussion of agile planning tools and digital tabletops. To support agile planning teams, a lot of research has been devoted to setting up a communication platform that allows for agile planning. In this chapter, I will list some typical project planning tools, and compare them to uncover their advantages/disadvantages.

Digital tabletops might be an applicable approach to provide better user experience than existing agile planning tools. The second part of this section reviews co-located and distributed tabletop studies and points out aspects that might benefit agile planning meetings.

2.1 Tools for Agility

Several project planning tools were created to support agile development. Most of them are designed for managing and sharing agile planning data in an asynchronous manner. Few tools support agile planning meetings that rely on synchronous communications.

2.1.1 Wikipages

Wiki-based [What is Wiki, 2002] agile planning tools utilize Web technologies to publish, manage, integrate and distribute agile planning information. The advantage of using Wiki-based systems is that they provide a flexible environment, making it easy to check project status, update task lists and view the team members' work progress. Wikis are an asynchronous platform for agile developers' communications. The following scenarios show how it is used by an agile development team:

Publishing story cards: After a project planning meeting, new wiki pages will be created to publish all the card information. Software developers and project managers will be able to access the wikipage and check their tasks.

Story card management: software developers are responsible for accessing the wikipages and updating their cards every day. Updating the card status facilitates managing the development progress. Meanwhile, the developers' efforts can also be realized by their colleagues.

Sharing knowledge: a software developer can post his/her questions to a wiki, and his/her colleagues can view the questions to provide assistances. Meanwhile, one developer's experience of solving some critical problems can also be posted on the wiki to provide help to his/her teammates.

Wikis support asynchronous interactions within the agile planning process. Moreover, using wikipages does not rely on any specific software on the client side (any web browser will do). However, agile planning meetings discussed in this thesis are a typical synchronous activity that are not by supported by wikis.

2.1.2 Web Form-based Application

Web form-based applications are often used for publishing and managing agile planning data. Compared to Wiki pages, Web form-based applications provide more sophisticated functions to manipulate agile planning data. The existing Web form-based agile planning tools include Rally [Rally's Agile Life Cycle Management Solutions, 2007], VersionOne [Agile Project Management Tools, 2007], ScrumWorks [ScrumWorks Basics, 2007], and some open source products like XPlanner [XPlanner Overview, 2007]. These applications use Web forms to create and manipulate data. They also set up basic workflows for sharing data amongst distributed agile developers. Figure 2-1 shows a screenshot of the Rally tool.

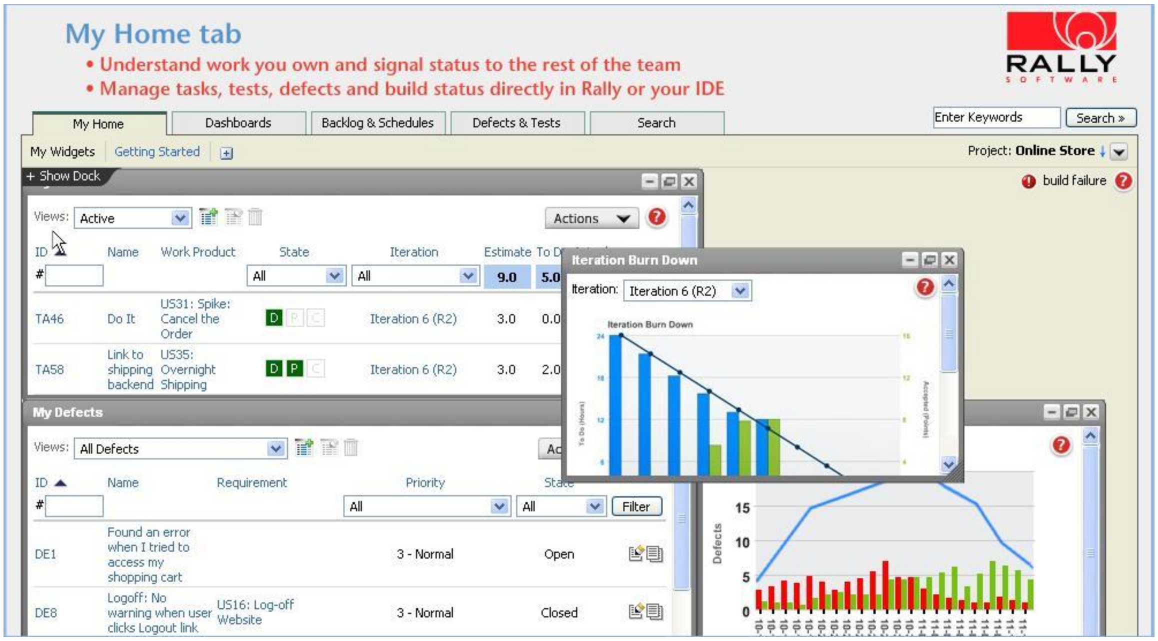

Figure 2-1: Rally tool interface

This screenshot shows agile planning data are better organized by Rally than by Wikipage. The tool supports several user interactions. For example, users can change the status of a story card by clicking the status button. They can also update the estimated working hours or descriptions of a task. By reviewing card histories and present card sets, the Rally tool generates a burn down chart to help project managers and team developers understand progress of their projects. Besides the functions of publishing, managing story card which is already provided by Wikipages, Web-form based application supports additional features.

Bindings story cards with source code: IBM Jazz [Jazz Overview 2009] provides an Eclipse-based client to enable software developers mapping their story cards with specific source code. The navigation between cards and source code bridges the high level project planning data with low level code segments.

Viewing charts: Most Web-based tools provide charts to help product managers reviewing their software development progress, such as counting working hours. Viewing charts is more intuitive than reading plain texts on wiki pages. The structured information stored by web-form based applications supports mathematical operations on the data (which is difficult and less accurate based on text stored in wikipages).

Web-form based applications highlight the analysis of project planning data and the management to story cards. They visualize agile planning data and create several views to help both software developers and project managers to understand their tasks and the whole project progress. However, they are still an asynchronous project planning tool and do not provide synchronous updates during an agile planning meeting, which is the main scenario of this thesis.

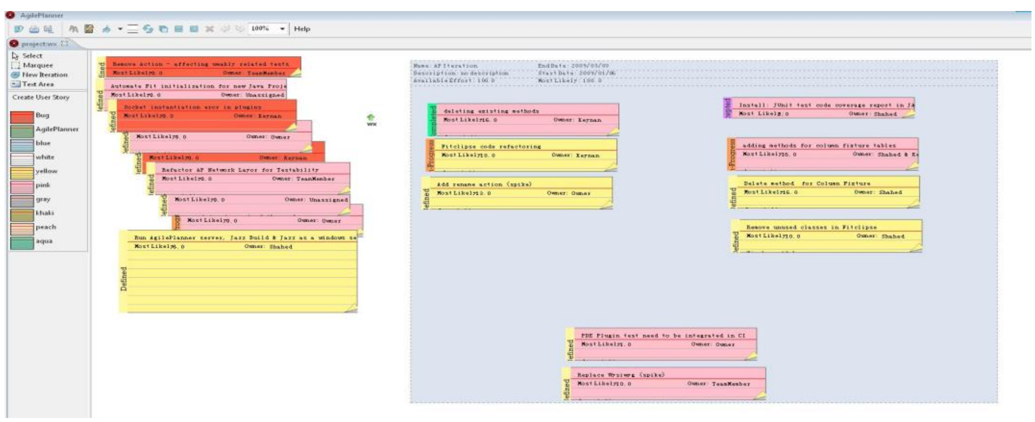

Figure 2-2: Screenshot of DAP

2.1.3 Distributed AgilePlanner (DAP)

The researchers in the Agile Software Engineering Lab realized the importance of using tools to support agile planning meetings. Morgan developed Distributed Agile Planner

(DAP) [Morgan, R., & Maurer, F. (2008)]. It is a synchronous, card-based agile planning environment. DAP provides a simple canvas to simulate a whiteboard in a meeting room. It also generates electronic index cards to simulate paper index cards. The user interactions of DAP include creating, moving and deleting cards. It attempts to support basic agile planning activities that can be observed in traditional, co-located and physical table based settings. To support distributed collaboration, DAP provides telepointers [Gutwin & Greenberg, 1998] to represent mouse pointers of remote clients. The position of a telepointer is updated in real-time. Thus, a collaborator can be aware of his/her remote partner's mouse movement just like looking at hand movements in a traditional co-located meeting. Figure 2-2 shows the interface of the distributed agile planner, on which a list of story card and iterations are displayed. The green arrow is the "telepointer" which acts as a remote mouse pointer to indicate the focus of remote collaborations. However, DAP was developed for a personal computer featuring single mouse input. When using DAP to organize a remote meeting, developers of a co-located sub-team must share a single mouse and keyboard control. However, agile planning meeting is essentially a group activity based on concurrent operations. Therefore, single mouse and keyboard makes it inconvenient to use DAP for multi-user agile planning meetings.

2.1.4 Comparison of DAP based- with Physical Table-based meetings

Wikipages and Web-form based applications are developed for sharing and managing agile planning data. They effectively support asynchronous agile planning, but do not help during synchronous agile planning meetings. In this section, I will exclude the wikpage and web-form applications and concentrate on the review of Distributed Agile Planner. I will compare it with traditional settings (pen-paper and physical tables) and identify some aspects that can be improved.

Liu proposed some criteria to reveal the qualification of agile planning tools in support of agile planning meetings [Liu, 2006]. The criteria are categorized into two parts. “Functional requirements” focus on the ability of using an agile planning tool to complete project planning, such as creating cards, iterations within an agile planning meeting. It shows whether agile planning can be supported. While “Interaction-related requirements” examine agile planning tools from the perspective of usability. It highlights “handwriting input”, “concurrent interaction” and “interaction with physical objects”. This part shows “how well” a tool can support agile planning. Here I use these criteria to evaluate tools mentioned in this section. The results are shown in Table 2-1. In this table, green cell with V means the function is available, while the red cell with X means it is not available.

The comparison indicates that DAP provides basic functions for agile development teams. However, it has some common issues when fulfilling the requirements of user interactions. DAP was developed for a single user per site. Thus, it is hard to be used for concurrent interactions with the planning information on a single site.

Although pen-paper based agile planning meetings can support group concurrent interactions, they cannot be distributed across multiple sites, thus the planning information is not directly shared with remote teams and requires manual replication. To better support agile developers, a synchronous communication platform should be provided. Meanwhile, concurrent interactions should be implemented on it. The following reviews of tabletop technology indicate that digital tabletops are applicable to set up such a platform for agile development teams.

Table 2-1: Comparing DAP- with Pen-paper- based meeting

Criteria	Criteria Sub Categories	Pen-paper	DAP
Agile planning objects creation and editing	Functional Requirements	V	**V**
Visual characteristics for different types of story		V	**V**
Agile Planning metrics management		X	**V**
Planning for multiple iterations		V	**V**
Systematic organization for planning objects		**X**	**V**
Fluid transition between plan changes and the consequent results		**X**	**V**
Real-time exposure of plan via Internet		**X**	**V**
Simultaneous planning information organization	Interaction-related requirements	V	**V**
Simultaneous planning information editing		V	**V**
Story editing with handwriting inputs		V	**X**
Handwriting recognition capability		V	**X**
Fluid transition between individual and collaborative work in agile planning		V	**X**
Fluid transition between agile tabletop collaboration and external work		V	**X**
Flexible user arrangement		V	**X**
Shared access to digital object in agile planning		**X**	**X**
Use of physical planning objects		V	**X**

2.2 Tabletop Technology for Agile Planning

A digital tabletop is an emerging Human-Computer Interaction device that supports multi-user interaction, concurrent operations and group collaborations. A digital tabletop, featuring a horizontal and tangible display is sufficiently different from personal computers and thus drives people to rethink “the use of a computer as a solitary act, the kinds of activities people want to do with computers, the types of social interactions that can be part of digital interactions, and how the interplay between digital and social needs can be supported” [Scott, S.D, Carpendale, S., 2006].

It has been realized that tabletops are applicable to support agile planning meetings [Liu, 2006]. The horizental display of digital tabletops changes the behaviors people interacting with computers. As most computers use vertical displays, there is only one top-down reading orientation. Rotating digital components of an application is thus not needed for traditional displays. To interact with vertical screen, people normally sit or stand in front of it. This hinders the group use of computer. However, a horizental screen allows users sitting around a tabletop, owning their personal space and requires different reading orientations on the table surface [Scott, Carpendale, & Inkpen, 2004]. It allows to simulate the approach that agile developers use to collaborate on top of phyisical tables.

The tangible tabletop surface can detect concurrent finger or stylus touches from different users. It overcomes the limitation of single keyboard/mouse control and enables multi-user interactions. Sensing the finger touches allows for implementing handwirting recognition, which enriches the way of input.

Having realized the potential benefits that might be provided by tabletops, I reviewed present tabletop hardware, as well as co-located and distributed tabletop applications. My literature review shows how to design my tabeletop-based application, meanwhile, indicating how I use my practical scenario (using tabletop for agile planning meeting) to benefit tabletop research.

2.2.1 Tabletop Hardware

A large number of companies and research institutes are devoted to the study and manufacture of digital tabletops. Interaction Lab in the University of Calgary customized a digital tabletop by using SMART DViT technology [DViT Technology]. . The DViT technology employs four cameras placed in each corner of the tabletop surface to capture and calculate the positions of at most two concurrent touch points. Moreover, the DViT technology can feel the "depth" of a touch point by sensing the distance of finger tip to the tabletop screen. DViT tabletop uses LCD to display the computer output. The SMART Table is another commercial product designed for educational institutes such as primary schools. It uses FTIR [Han, 2005] to sense more than 40 concurrent touches.

Microsoft provides its commercial product named "Surface" [Micrsoft Surface, 2009], which utilized camera-based vision system with LED infrared direct illumination. Employing the vision system, surface can not only sense incoming touches, but also recognize simple image patterns such as bar codes. It can also recognize the shape of a physical object as well as its orientation.

Digital tabletops are under a rapid development. However, only a small number of tabletops are commercialized. As end users of tabletop technologies, we have a DViT and a FTIR tabletop from SMART Technologies Ltd. Relying on commercial and near-commercial tabletops, my observation aims at uncovering under a practical environment, whether and how FTIR & DViT tabletops support co-located and distributed agile planning meetings. From the perspective of real-world usage, this study provides insights into benefits and limitations of existing commercial tabletops.

2.2.2. What Tabletops Do Agile Team Need?

The above descriptions reveal that present tabletop hardware varies (Wallace & Scott, 2008) in size, touch recognition mechanisms, the target user groups and the available functions. Based on the diversity of tabletop hardware, a question is to be answered – what tabletop is appropriate for our agile planning meetings?

Wallace and Scott [Wallace & Scott, 2008] studied co-located, collaborative tabletops from the aspect of contextual design considerations. They proposed five contextual factors in the tabletop design process. The factors are shown as follows:

1. *Social and culture* refers to "the factors that impact the social and culture norm that govern group behaviors in a given context". For example, the use of tabletop is for casual experience or formal activities with social pressures.
2. *Activity context* refers to the type of tasks that the group is engaged.
3. *Temporal context* means how long and how often tabletop is used by the group
4. *Ecological context* shows the environment that tabletop will be used, for example at home or in the office.
5. *Motivational context* means the goal that groups want to achieve from using tabletops, for example, users desires for a "fun and socially enjoyable" experience or pursue an "efficient decision making with complex data".

Wallace and Scott then discussed how these five factors influence the design of three main aspects of tabletops system. The aspects are: **software interface** which refers to how the application should be designed on tabletop. It highlights the design of software running on tabletops. The **physical form** shows the physical parameters such as the height and size of tabletops. It refers to the hardware design of tabletops. The

connectedness involves how tabletop connects with external objects, such as laptops or paper documents. They provided some suggestions for different tabletop usage scenarios (such as a not frequent use of tabletop for gaming scenario). In this session, I use the suggestions to identify agile planning meetings and try to find some guidelines for the selection of digital tabletops. The finding is shown as follows:

Table 2-2: What tabletop is need for agile planning meetings

Criteria	**Social**	**Activity**	**Temporal**	**Ecological**	**Motivational**
APDT	With social pressures	Planning Meeting	Not frequent	Office	For comfortable meeting experience
Interface	1. Provide simple interaction components with obvious visual affordances. 2. Pseudo-physical object and interactions are suggested. 3. Avoid complex gestures beyond single touch pointing and dragging				
Physical form	1. No strong requirements to workspace awareness 2. Provide comfortable accommodation for users 3. Users could sit at the same side.				
Connect-edness	1. Connecting with the Internet. 2. Allow the use of physical object, such as paper documents and coffee mugs on tabletop				

The guidelines are proposed by the consideration of different contexts. For example, as a tabletop is not frequently used by an agile team (only for agile planning meeting that happened once per two weeks), keeping agile developers remembering the use of tabletop-based agile planning tools might be challenging. Therefore, using pseudo-physical objects and interactions, such as creating digital story cards which has identical appearance as paper cards and designing digital card interactions similar to paper ones may reduce the users' learning curves. Using pseudo-physical objects is also suggested when considering the social context of agile planning meetings. According to Wallace and Scott's theory, using some user-familiar objects will help release the learning curve and, thus, create a convenient experience.

The size of digital tabletop is another important factor to be considered by tabletop designers and users. Wallace mentions that the table size might be influenced by the users' age and culture, the amount of materials that might be used for the activity and the type of activity (cooperation is better supported by sitting at adjacent side while competitive activities is supported by opposite seats. Ryall et.al. [Ryall, Forlines, Shen, & Morris, 2004] concentrate on the effects of group size and table size on interacting with table-based groupware. Their study considered the impacts of seven aspects – resource management, work strategy, social interactions, display resolution, physical reach, visibility and tasks. Their conclusions indicate that

1. The size of table does not affect the speed of task completion while the group size does,

2. people will change their work strategy to fit the tabletop size and

3. for large groups, designers need additional device (such as large display) to share information.

Defining an appropriate table size for all the agile planning meetings is unlikely successful because the agile development teams vary in the size of groups, the culture background, age and the type of social interactions. There is not yet a mature theory to help determining a single tabletop size based on different amount of group members with specific types of tasks. However, the following statements will still hold when a table size is to be decided by an agile team.

1. The size of tabletop should be large enough to guarantee all the participants feel comfortable when they sit together. Social pressures due to too-small gaps between neighboring seats should be avoided when choosing a tabletop.

2. There should be enough space on the table to put materials, such as paper documents, notepads and coffee mugs.

3. There is no benefit of using an over-sized table because it will not increase the speed of task completion.

4. When using a large table, a designer should carefully consider the impact of visibility and physical reach. Other approaches such as using an additional display for sharing information might help to overcome the negative effects of large tabletops.

2.2.3 Tabletops in this Study

We have a DViT and a FTIR tabletop in our lab (see Figure 2-3). DViT tabletop is a customized product manufactured by SMART Technology. It is based on a 183 cm x 122 cm x 122 cm stand. It provides a large surface round which 8-10 people can stand or sit and interact. To allow participants to bring their personal belongings, each side has a 30 cm wide border to place notes, palm, pens or coffee mugs.

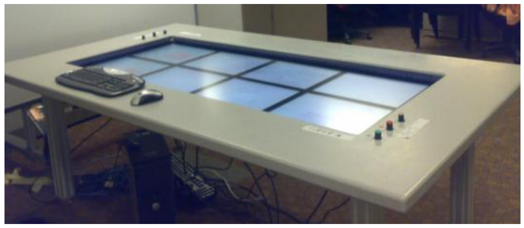

Figure 2-3: DViT and FTIR Tabletops

The DViT table is composed of eight LCD screens. Each screen has a native resolution of 1280 x 1024 pixels. As a result, the table displays approximately 10 Megapixels. Compared with commonly used projectors, it has a higher resolution than the SMART FTIR table.

The FTIR Table is a commercial product geared towards collaborative learning and entertainment. The display of the FTIR Table is composed of a plastic, semi-transparent canvas and a projector hidden inside the tabletop. The display has a 1024 x 768 resolution and displays 0.7 Megapixels. The table surface is 91.1 cm wide and 64.8 cm deep. The FTIR Table is driven by a personal computer. However, since it is built on a projector, the contrast ratio and brightness is not as excellent as the SMART DViT-based table, which utilizes LCD screens.

Both of the tabletops vary in the capabilities of recognizing concurrent touches. The DViT tabletop recognizes only 2 touches but FTIR tabletop recognizes more than 40 touches. Using the tabletop criteria proposed in Table 2-2 to review the two tabletops, I find that both of them have some limitations that might hinder the user experience. For the large DViT table, although it provides a border to put the personal belongs and meeting materials, it only allows two concurrent touch points which might not provide free interaction for every user. Because the small FTIR table can support no more than 4 participants, the size of the agile team will be restricted. Also, it is hard to put many physical objects on the table.

2.2.4 The Studies of Co-located Tabletop Applications

Co-located tabletops change the way of people interacting with computers. With the involvement of a horizontal display, and concurrent use, digital tabletops provide a different user experience compared with conventional computers.

Territoriality and reorientation: Tang [Tang, 1991] investigated the work practices during collaborative design on a table. Her findings reveal orientation and partitioning plays an important part to coordinate group users' activities. Tang's statement was proven and further analyzed by Scott and Kruger. Scott [Scott, Carpendale, & Inkpen, 2004] studied partitioning in tabletop interfaces. Her research reveals that collaborators use three types of tabletop territories to help coordinate their interactions within the shared tabletop workspace: *personal*, *group* and *storage* territories. Kruger [Kruger, Carpendale, Scott, & Greenberg, 2003] conducted research on how people use orientation on tables. His findings revealed that orientation of tabletop items plays three key roles during tabletop collaborations: *comprehension, coordination and communication*.

Touch vs. mouse: Hornecker [Hornecker, Marshall, Dalton, & Rogers, 2008] compared mouse and touch collaborations within a co-located, DiamondTouch [Dietz, P.J., Leigh, D.L., 2001]-based group. Her conclusion reveals that by using a co-located tabletop, finger touch is seen more positively than mouse usage to support collaborative interactions. Moreover, she discusses some negative and positive indicators to show the level of collaborative awareness among group users. Negative indicators such as interferences (grabbing the same objects) or verbal mentoring ("what did you do there?") indicate a lack of collaborative awareness. Some positive indicators, such as reactions without explicit request and object handover without verbal coordination are listed to indicate the smoothness of group collaborations.

Gestural and speech recognitions: Single touch-based gestural interactions have been implemented by many touch devices such as Tablet PCs and SMART Phones for several years. Microsoft, for example, defines a series of single-touch gestures to support Tablet PC users.

Utilizing the multi-touch capabilities of tabletops, multi-finger and whole hand gestural interaction is more sophisticated than single touch gestures. Based on Diamond Touch Table, Wu [Wu & Balakrishnan, 2003] developed a series of multi-finger and whole hand gestures for their RoomPlan application. Tse [Tse, Shen, Greenberg, & Fortlines, 2006] combined two hand gestures with speech commands. His application is deployed on Google earth and Warcarft –III.

Although gestures are suggested as intuitive methods of input for tabletops, it is not yet clear whether users would like to use them. Meanwhile, we also need a comparison to indicate the user preference between the several of gestural interactions. Epps et.al [Epps, Lichman, & Wu, 2006] provide a study of different hand gestures. They evaluated index finger (single finger touch), spread hand, flat hand, grab/release vertical hand/ fist and other hand shapes. Interestingly, using the index finger receives 70.1% preferences, which is much higher than the second one – spread hand (20.0%).

In this study, I decided to use single touch based gestures. Speech control is also explored by using .Net Speech Recognition Engine. The decision is made for the following reasons:

1. The DViT table only allows two touches. It cannot recognize hand shapes.

2. Epps' study indicates that index finger (single finger gesture) is more welcomed than more sophisticated gesture definitions.

3. Wallace's study showed that for a non-frequently used tabletop, simple gesture definitions are much better than sophisticated one considering the burden of learning and remembering the gestures. The statement can also be proven from the aspect of social pressure (sophisticated gestures do not fit the activities that have some social pressures, such as formal meeting).

4. Table interactions in agile planning meetings are not as sophisticated as the scenarios (tag map and playing game) provided by Tse. There is no need to combine touch and speech interactions for producing advanced semantic.

2.2.5 The Studies of Distributed Tabletop Applications

Interactive digital tabletops can facilitate group collaborations in a co-located environment. However, a large number of group activities are conducted in a geographically-separated environment. Therefore, a lot of effort was made to investigate the possibilities of linking together remote tabletop displays in order to create a shared workspace for remote collaborations. Esenther and Ryall [Esenther & Ryall, 2006] studied distributed table collaborations by proposing a DiamondTouch-based tool – Remote DT. It suggests three modes to interpret touch interactions on tabletop surfaces.

"Mouse mode" emulates PC mouse actions. "Annotation modes" interprets finger movements into ink strokes, and uses the strokes to annotate the table screen. "Telepointer mode" creates the telepresence of remote touches. By exploiting DiamondTouch's capability of identifying specific users, color-coded text labels are created to indicate who is touching where. Remote DT explores the telepresence of remote users. However, their evaluations did not use multi-site groups and distributed tabletops. In their study, only one tabletop is used and other individual participants used desktops at remote sites. Feasibilities of using distributed tabletops for group-to-group collaborations are not touched.

Tuddenham and Robinson [Tuddenham & Robinson, 2007] proposed a design guideline for distributed tabletops. They enumerated the characteristics that should be provided by a distributed tabletop:

- A large horizontal display surface.
- Collaborators sit in different positions around the edge of the surface.
- Direct input mechanisms (stylus or touch).
- Digital artifacts can be moved and freely reoriented.
- Collaborators can see each other's arms by showing digital arm shadows.
- Simultaneous interaction by multiple collaborators.
- Collaborators can see each other's bodies and faces.
- Collaborators can talk to each other.

Compared to the study of co-located tabletops, their research highlights the impacts of "virtual seat arrangement" and "arm shadow" visualization. To implement the factors, top-mounted cameras are used to capture the shadows of arms on table surfaces.

Gutwin et al studied the workspace awareness in real-time distributed groupware [Gutwin & Greenberg, 1996]. His research, although not related to tabletops, uncovered some elements of workspace awareness that mirror concepts from tabletop studies. For example, the “identify, location and actions” he highlighted can be interpreted as “user identification”, “virtual seat awareness” and “body gesture visualization” in a tabletop context.

Tang [Tang, Boyle, & Greenberg, 2005] proposed Mixed Presence Groupware (MPG) to support both co-located and distributed participants working over a shared virtual workspace. His study utilized SDGToolkits to support multi-mouse pointers. He also used GroupLab Collabrary for video and audio capturing. A Video Whiteboard is used for capturing digital arm shadows. Tang’s experimental setting supports user identification, seat awareness and remote arm visualization. However, it is difficult to migrate his environment to my study. The SDGToolkit recognized different mice rather than the person who holds the mouse. For tabletops, the SDGToolkit can support the identification of touch sequence (such as the first, second touch) but not the owner of the touch. Seat awareness and arm shadow also depends on specific tools and hardware, which are beyond the tabletops used in my experimental setting.

2.2.6 The Non-Optimized Environment

The above studies point at an “optimized” environment in which “user identification ”,”seat awareness” and “body gesture visualization” are implemented. However, except in the Diamond Touch, these technologies are not yet commercialized. There is no guarantee that the techniques will be pushed into the market.

While current devices are incapable of providing desirable features like user identification and arm shadow support, this does not necessarily indicate the incapability of supporting tabletop-distributed agile planning meetings. This thesis will use the FTIR and DViT SMART tables to expose how or to what extends distributed agile planning meetings are supported by using commercialized or near-commercial tabletops.

2.3 Summary

This chapter provides an overview of existing studies on agile planning tools and digital tabletops. An analysis of present agile planning tools indicates that they suffer some usability issues due to the use of vertical displays. Using digital tabletops will provide new features. The horizontal, tangible and multi-touch screen of a digital tabletop should provide better user experience than a traditional personal computer. The horizontal display of a tabletop allows group collaborators to improve the readability of artifacts by reorienting them. A tangible interface can recognize finger gestures, thus supporting more interactions than mouse events. A multi-touch surface allows users access to the digital table simultaneously. Based on this analysis of digital tabletops, I developed a new agile planning tool – AgilePlanner for Digital Tabletop (APDT). The evaluation of APDT will demonstrate the feasibility of using a digital tabletop to support agile planning meetings.

In order to provide a solid basis to design APDT, studies of tabletop technology were reviewed. Based on the literature on co-located and distributed tabletops, some important factors, such as the selection of input mechanisms, personal territoriality, and the telepointers are carefully considered.

CHAPTER 3: AGILE PLANNER FOR DIGITAL TABLETOP

Agile Planner for Digital Tabletop is based on the project "Distributed Agile Planner (DAP)" which provides a full set of functions for distributed and co-located agile planning meetings [Morgan, 2008]. However, DAP is designed for a vertical screen, which has been shown to have some drawbacks, particularly the usability issues in support of group interactions (see Table 2-1). Meanwhile, my literature review highlights the potential benefits of employing tabletop technology for both co-located and distributed agile teams. Thus, I want to design AgilePlanner for Digital Tabletop (APDT) which:

- Support basic project planning activities by migrating the functionalities of DAP to digital tabletops [Wang, Ghanam, & Maurer, 2008].
- Utilize interaction features of digital tabletops to enhance group collaboration.

3.1 Development Context

The first prototype of APDT was designed by Weber [Weber, Ghanam, Wang, & Maurer, 2008]. His version initialized the APDT interface and defined some agile planning artifacts such as digital story cards and iterations. He also explores the use of handwriting, voice and gesture recognitions in APDT. He contributed to establishing the basic layout and interactions of APDT and provided fundamental implementation support to this thesis. His prototype was further developed for the following reasons:

1. The prototype only works for single touch.
2. It is a local version. No distributed feature is provided.

3. It could not exchange planning data with other agile planning tools, such as the Rally Tool and IBM Jazz.
4. The interaction design was prototyped but not evaluated. My evaluations resulted in substantial changes of the interaction design to overcome usability problems detected in the studies.
5. The prototype was not yet evaluated in a real-world agile planning setting. Thus, it was not clear whether the digital artifacts (story card and iteration) and functions is enough to support agile planning activities. I added some additional concepts (particularly, telepointers, state areas) to overcome some limitations encountered by the team.

The first version of APDT was released in April 2008. It supported co-located planning meetings. Based on this version, a formal evaluation was conducted to explore using tabletops in a co-located environment. The results are shown in Chapter 4. The second version aims at supporting distributed agile teams. It has a shared interface to display index cards, and uses telepointers to show the behaviors of remote participants. An evaluation of the distributed APDT was conducted in November 2008. The results and analysis will be reported in Chapter 5. The following of this chapter illustrates APDT. It describes the design of digital artifacts, the interaction approaches, the distributed facilities and the implementation.

3.1 Digital Artifacts

The story card is a core artifact for agile planning. It records a task with its owner(s), estimated working hours, actual working hours and related descriptions. APDT’s digital story cards, as seen in Figure 3-1, are nearly identical in appearance to traditional paper cards. By mimicking physical cards, APDT creates a card-centered environment. APDT users are allowed to input card name, task descriptions, mostlikely hours (the expected hours that will be used to complete the task), actual hours (the work hours actually used on the task) as well as selecting the card owners (from members of the agile team). A handwriting button is placed at the middle right of the card. Clicking the button will enable handwriting mode which allows users to write directly on the card body.

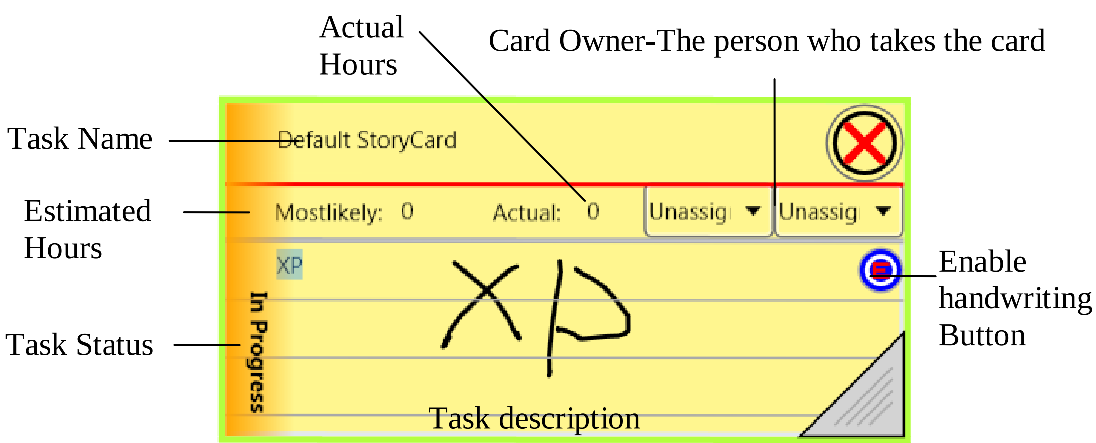

Figure 3-1: Digital Story Card

In APDT, an iteration contains story cards. Iterations represent development timeframes in agile development processes and usually run for 2-4 weeks. A digital story card can be dragged into or out of an iteration to indicate the inclusion or removal of their dependency. Moreover, an iteration will dynamically calculate its estimated effort by summing up the expected effort of each story card. This makes it convenient for an agile team to control the total efforts of an iteration. In Figure 3-2, the available hours have been assigned to 10 hours. It means within this iteration, a total of 10 hours could be used. While two story cards are place into the iteration and they consume 4 + 5 hours as most likely efforts, only 1 hour remains flexible for this iteration. Supposed that another story card which consume 2 hours (Mostlikely = 2) are dragged into the iteration, the remaining effort will become 10-4-5-2= -1 hours. Obviously, it is not reasonable. By realizing the unreasonable arrangement, agile teams can rearrange the tasks for this iteration, or increase the available working hours for this iteration, such as including more developers.

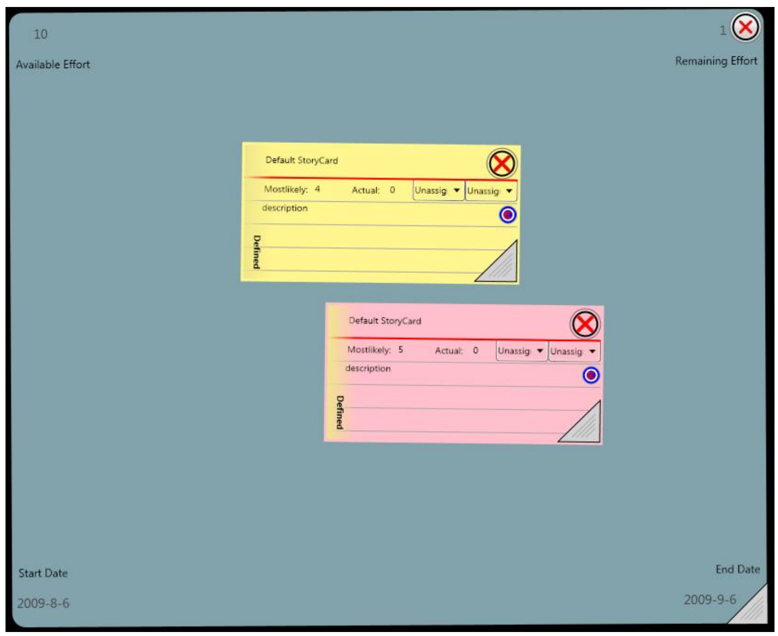

Figure 3-2: Iteration with story cards

Status Area indicates another way to organize story cards (tasks). Every card that is dragged into status area will switch to the same status that is tagged on the left side of the area. It is proposed to meet the requirements from agile developers. Sometimes agile teams would like to group cards by their status. It is easy to check how many tasks are proposed but not yet started while how many tasks are in progress.

Status Bar

Figure 3-3: Status area

APDT's UI widgets expand the traditional WIMP metaphor (window, icon, menu and pointer). An application using WIMP often docks its widgets such as menus, icons, and buttons to a fixed orientation, e.g. a horizontal or vertical bar. This layout works well on a PC screen with a defined vertical orientation. However, APDT is deployed on a digital tabletop featuring a horizontal display, and the widgets must be orientation-independent so that collaborators sitting at any location around the table can see and use them conveniently. In APDT, control widgets are placed in a central-symmetric Control Palette (see Figure 3-4). It can be rotated and moved on tabletop surface to facilitate users interacting with the control palette. This is made possible through implementation of a RNT-inspired (Rotate and Translate) algorithm by Hancock et al. [Hancock, Vernier, Wigdor, Carpendale, & Shen, 2006]. The control palette consists of a server connection box, a Jazz synchronization box and a main panel. The main panel contains some color buttons to change the color of story card. In a real-world usage, the color may indicate the property of tasks, such as red cards often represent the tasks of solving bugs. The server connection box allows users to connect APDT to a meeting server and choose related project files under the server. A project file represents a meeting scenario. It records story cards, iterations, status areas and their positions on the screen. Jazz synchronization box enables APDT users to exchange project file with IBM Jazz [Jazz Overview (2009)], another project planning tool.

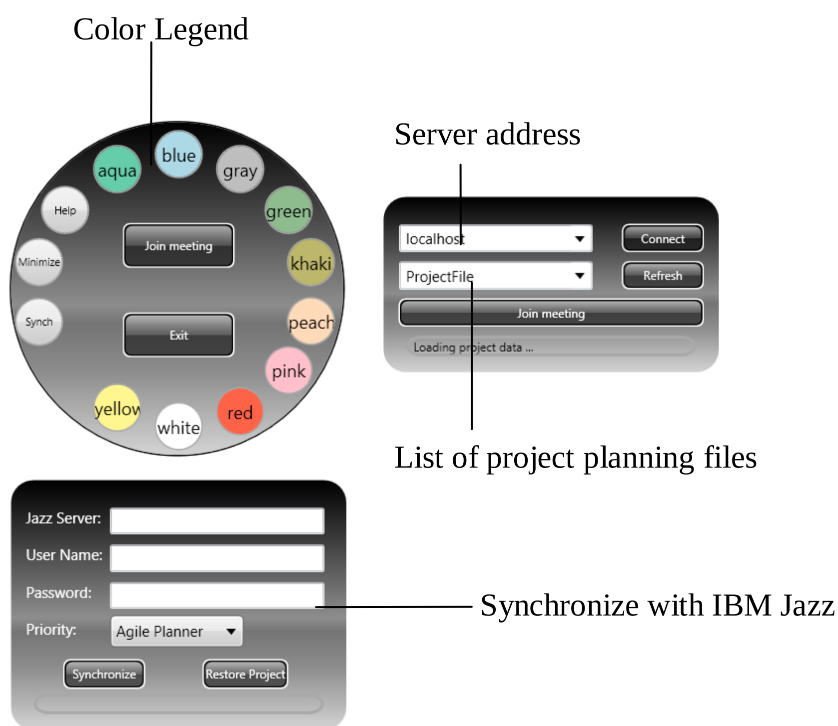

Figure 3-4: Control palette

3.2 Functions

Table 3-1 lists APDT's functions and compares them with those of computer and pen-paper based agile planning meetings. From this comparison, we realize that APDT not only migrates the functions of DAP, but also simulates some operations, such as tossing and rotating cards from pen-paper based meetings.

Table 3-1: Pen-paper, Tabletop and PC based Agile Planning Meeting

Core Activity	**Pen & Paper based planning**	**PC based agile planning (DAP)**	**Tabletop based agile planning (APDT)**
Create card	Fetch a new paper card and put it on the table.	1. select card model 2. drag it to the canvas	Use finger gesture (shown in Figure 3-5) to create a new index card at the location of the gesture.
Move/Rotate card	Hold the card and put (rotate) it to the target position.	1. select card 2. move it [Rotation is not available]	Use a finger to press the card, make the card move with the finger to a target position.
Toss card	Throw card on the table surface or pass it from hand to hand.	N/A	Use a finger to swipe card, toss it into the target direction.

Delete card	Trash the card.	Select the card Click delete button	Draw a "scratchOut" gesture over the targeted card boundary. [or click the delete button in the top-right corner of the card]
Resize card	N/A	drag the card border	drag the bottom right corner of target card.
Undo/Redo	Depends on the operation (e.g. wipe the card contents out and write it again).	Click undo/redo button on menu bar	Use gesture to undo/redo last changes.
Select card	Point to/Pick up the target card.	1. Click the card	Touch the card with finger tip.
Save cards	N/A	Project automatically persisted	Project automatically persisted
Change color	N/A	1. select card 2. Click color button on menu bar	Select card Use finger to click relevant color on Control Palette

Edit Card	Write on the card with a pen.	1. Activate textbox 2. Use keyboard to input	Use finger or stylus to write, erase handwriting on the card. Handwriting will be converted to text by recognition engine. [or select text field and use keyboard to enter text]

3.3 Interactions

Table 2-1 shows that the basic issues of current agile planning tools are that they are lacking support for group interactions. Based on usability features (horizontal, large and tangible display) of digital tabletops, APDT is designed to support synchronous group collaborations. Using tangible and multi-touch tabletop screens, I developed finger gesture controls, handwriting inputs and multi-touch to enhance the user experience. Speech recognition is well supported by using the newest .Net framework. In APDT, I added speech command control to explore whether using speech to control the meeting process is beneficial.

3.3.1 Finger Gesture Control

APDT is deployed on a digital tabletop featuring a touch-sensitive interface. Thus, APDT is designed to employ the tangible surface of tabletops. It recognizes touch gestures and binds the gestures to various operations. Figure 3-5 lists the gestures defined in APDT [Application Gestures and Semantic Behaviors, 2009]. For example, by drawing a square, a user creates a new iteration which will be displayed at the position where the gesture was drawn. Drawing a circle will create a control palette at the center of the gesture.

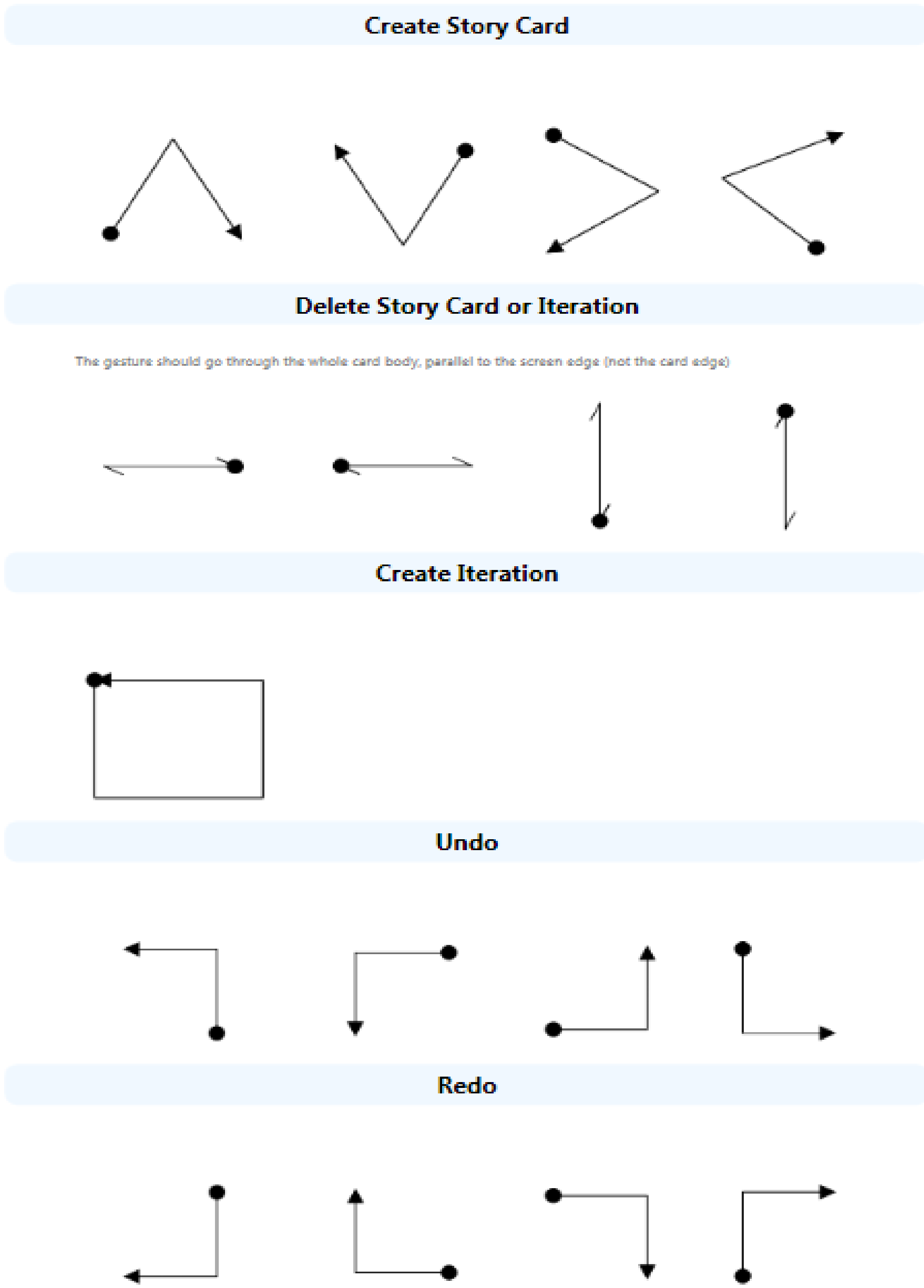

Figure 3-5: Gestures used in APDT

Gesture recognition simplifies user interactions. For example, in PC-based agile planning meetings, creating story card consists of five steps:

1. Find the position of mouse.
2. Find the position of story card model
3. Move mouse to the model at a menu bar.
4. Drag the card model into the main canvas.
5. Release mouse button.

However, using APDT to create story cards neither requires use of the mouse, nor use of UI widget. Participants can stand at any position around the table, using their fingertips to draw a "chevron up (^)" gesture. The newly generated story card will be displayed at the position where the gesture was drawn.

3.3.2 Speech Command Control

Speech command controls employ voice recognition technology to convert the human's voice to computer recognizable commands (see Table 3-2). For example, if a collaborator says "create story card", a new story card will be displayed at the center of the APDT interface. Voice recognition is an exploratory attempt at using verbal commands within agile planning meetings. The voice commands, with gesture recognition, are expected to provide multiple choices for APDT users to interact with tabletops.

Table 3-2: Voice commands and user interactions

Voice Command	User Interaction
Create story card	Create a story card and display it at the center of the tabletop interface
Create iteration	Create an iteration and display it at the center of the tabletop interface
Delete card	Remove the currently-activated story card or iteration from the tabletop interface
Highlight/Select	Showing the card ID on the surface of an activated card
Previous Card	Switch to the previous/next card in terms of card ID
Next card	

3.4 Multi-touch

Multi-touch is supported by APDT. It allows group collaborators to interact with a digital tabletop by drawing gestures or operating (such as moving, rotating and tossing) index cards simultaneously. However, as digital tabletops are not yet standardized. Different hardware platforms vary in the way they recognize touch points. Respectively, to support multi-touch, an application must be compatible with hardware SDKs of a target table. The multi-touch of APDT is working on SMART's DViT and FTIR tabletops. However, to migrate it for other tabletop platforms, such as Microsoft Surface, additional efforts must be made to change APDT so that it can use new SDK to drive touch recognition.

3.5 Handwriting Input

Traditional agile meetings employ pens and papers to record planning data. Handwritten information is used broadly, although at time it can be hard to read. On APDT, an ink canvas is placed on a story card to collect stylus ink strokes. A handwriting recognition engine is used to translate handwriting to computer-accessible text. Moreover, handwritten strokes are always displayed on a card body until they are erased or the card is deleted.

3.6 Distributed Features

To support distributed agile planning meetings, I created a shared workspace for remote communications. The workspace should propagate collaborators' interactions to remote locations.

3.6.1 Telepointer

The telepointer – a remote "hand icon", is used to represent each touch on a remote tabletop surface. When a participant is touching a tabletop which is running APDT, a telepointer is created and displayed on every connected APDT client. Since the position of this telepointer is updated in real-time with respective finger movement, local collaborators are made aware of their remote collaborators' finger actions and their focuses through watching the telepointers. To identify a touch point, a telepointer is combined with a name tag to identify different touches based on the touch sequences on the surface (see Figure 3-6).

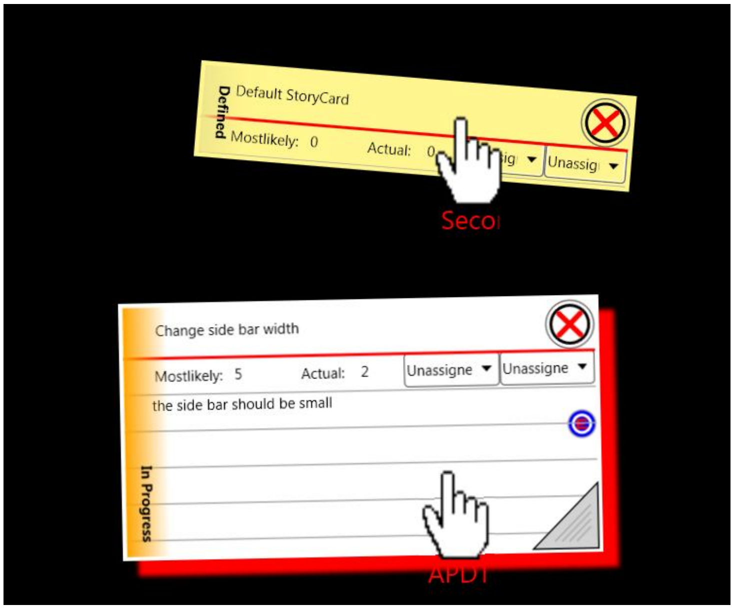

Figure 3-6: Telepointer pointing at a story card

3.6.2 Synchronous Workspace

An important factor affecting the experience of remote users is whether they can interact with a shared workspace. APDT provides a synchronous workspace to show the identical information on each site. A typical example is when a participant is moving a story card on the workspace. Remote participants will be aware of the card movement by observing its real-time position updates, as well as possible card rotations. Other important synchronization involves creating a new card, deleting card, resizing card and live update (the keyboard interactions from one location are simultaneously broadcasted to other locations). Changes of card properties, such as color changing can also be propagated.

3.7 Usage Scenarios

This session describes a sample scenario of two distributed agile team using APDT for their project planning meeting.

1. Start agile planning meeting: Both teams set up their meeting environment. Skype is used for their verbal communications. They test the quality of voice and then start APDT on both tabletops. They connect to the server, then pick up their project planning file from a file list. Card information will be retrieved from the file and displayed on both interfaces. They will also see the telepointers when their remote colleagues are touching their table.

2. During the project planning meetings: Some agile planning teams will firstly discuss the last iteration. In this process, completed cards from last iteration will be deleted. In progress cards will be moved to this iteration. Sometimes the card priorities will be adjusted considering that some tasks are no longer important to users.

Having reviewed former story cards, participants turn to plan the tasks for the following iteration. When a new task is proposed, a card will be created and displayed on both sides. The group then discusses who will be available for handling the card and how long it may take to complete the task. Discussion results will be documented by editing the card. Once the card is set up, it will be passed or tossed to its owner (the person who is responsible for the task). The card owner will rotate the card. The process is repeated until all the customer requirements are proposed as new cards and assigned to specific developers (or placed in the backlog of future work). At the end of this meeting, cards will be dragged back to the center of the tabletop. Customer representatives from both sites will rank cards based on their priorities and come to an agreement regarding development priorities for the iteration.

3. Finishing up the meeting: When both sites are satisfied with the output of agile planning meetings, they stop discussion and exit APDT. The card contents and positions will be automatically saved at the project planning server.

4. After project planning: In daily development, the agile developers edit their cards to update the development progress. APDT is integrated with personal project planning tools – DAP and progress tracking tools – IBM Jazz. The software developers can manipulate and update the cards from their (DAP, Jazz) clients.

3.8 System Architecture and Implementation

In this session, I will illustrate:

1. the role of APDT in an agile planning context
2. the basic architecture of APDT
3. the implementation of multi-touch and gesture control

I hope the illustration will show enough details on how APDT is built. I also wish this session can help future developers implementing the similar agile planning applications.

3.8.1 The Role of APDT

Figure 3-7 shows the role of APDT in an agile planning context. APDT is a front-end application that allows users to create agile planning data based on a convenient meeting environment. The data is kept in an XML format and can be shared by other planning tools. A Java-based server is the medium for data sharing.

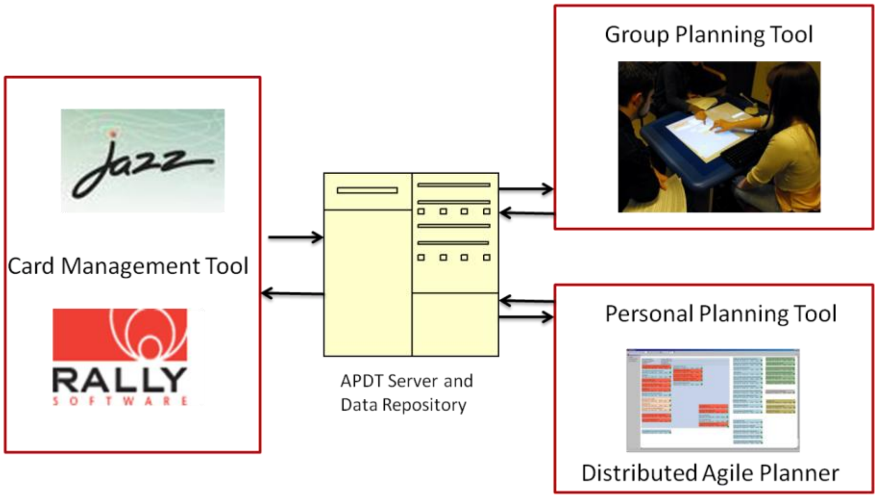

Figure 3-7: The role of APDT

3.8.2 APDT Architecture

APDT consists of two basic objects- *display object* and *data object*. Display objects are inherited from WPF framework element. By placed into a WPF window, they show digital artifacts on tabletop screen. In APDT, there are four display objects: StoryCardDisplayObject, IterationDisplayObject, StatsAreaDisplayObjects and Control Palettes. They integrate several UI widgets such as buttons, textboxes and combo boxes to support agile planning activities (such as select card owner). DisplayObject is also the sensor of touch interactions. Each display object is hooked up with TouchUp, TouchDown, and TouchMove handler to feel different touch events.

Display objects (except control palette) are combined with a data object. As a data source of display object, data object saves two types of data:

1. Agile planning data: The data that defines a story card and iteration. For story card, they are task name, task estimated hours, the most likely hours, task description and card owners. Iteration data object maintains the start and end date,

the available work hours, and a card set that contains the entire story cards within this iteration. StatesArea has the common status, and a story card set.

2. Data for card display. Data object saves the coordinator, rotation angle, width and height of its display object. The parameters are updated with the moving, rotating and resizing of its display object. The data helps initializing the display object when starting up the APDT.

Message Data Object is a special data object for information distribution. It has a message header that indicates the type of this message (to move a card or update its agile planning data). Its message body often contains an updated card data object.

Besides display and data object, other facilities are used to guarantee the establishment of a co-located and distributed agile planning meeting. XML reader and writer converts data object between class and XML-formatted string (see sample XML string)

SAMPLE of XML Formatted Project Data:


```xml
<Project ID="1" Name="ProjectFile">
<Backlog Height="0" ID="2" Name="Project Backlog" Parent="0"
Width="0" XLocation="0" YLocation="0">
  <StoryCard TestText="" TestURL="" Actual="0" Color="yellow"
BestCase="0" CardOwner="Owner" CurrentSideUp="0"
Description="description" Height="150" ID="3" XLocation="370"
YLocation="287" MostLikely="0" Name="Default StoryCard" Parent="2"
RotationAngle="-177.5707" Status="Defined" Width="300"
WorstCase="0" RallyID="" FitID="" />
  </Backlog>
  <Legend aqua="aqua" blue="blue" gray="gray" green="green"
khaki="khaki" peach="peach" pink="pink" red="red" white="white"
yellow="yellow" />
  </Project>
```

For co-located usage, the XML string is saved in a project file, while in a distributed mode, it is sent to remote APDT server.

Figure 3-8 describes the architectures of two APDT clients. It also demos how a user interaction is broadcasted to remote APDT interfaces. The demo is shown as follows:

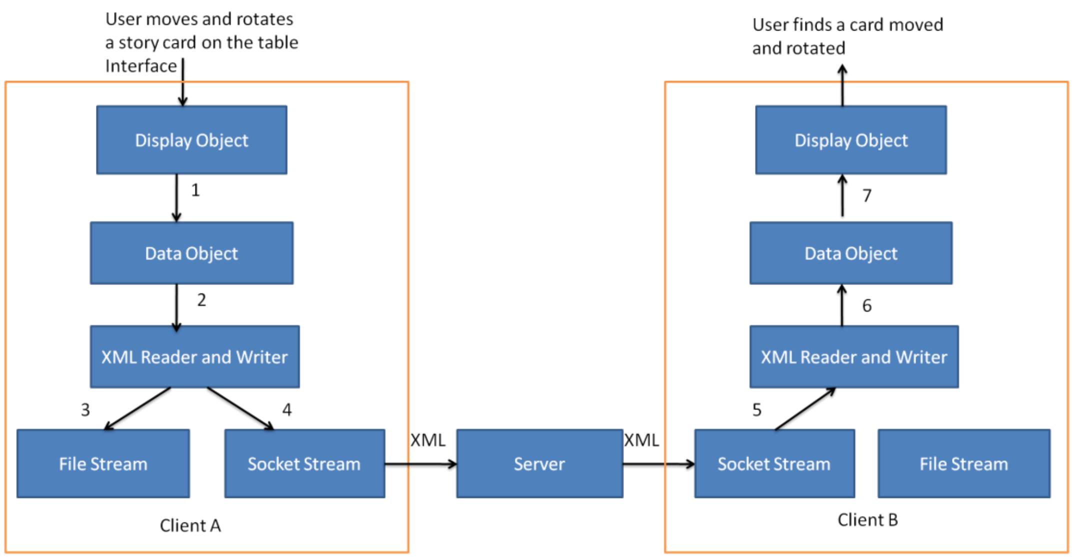

Figure 3-8: APDT architecture and its workflow

On client A, a user moved and rotated a story card. The card display object captured the touch events, moved itself to the new position with a new angle, then notified its data object to update the X, Y and Rotation Angle(1). Having completed the update to data object, client A created a message. The message header showed the type of event (position, angle update). The message body contained a copy of the updated card data object. Client A then called XML writer to convert the message into a XML-formatted data (2). In a co-located mode, the file stream read the XML data and used it to rewrite project file (3). In a distributed mode, the message was sent to server by socket stream (4).

When client B received the forwarded XML message, it called its XML reader (5) and converted the XML message to message data object. According to the message type, Client B found the StoryCardDataObject that should be updated and changed its X, Y. rotation angle according to the data object in the message body (6). The updated data object notified the new coordination and rotation angle to its display object (7).

3.8.3 The Implementation of Multi-Touch

Multi-touch is a core function for tabletop applications. Some advanced tabletops, such as SMART FTIR Table and Microsoft Surface, provide several UI controls, such as ScatterView in Microsoft Surface to support multi-touch. However, on DViT Table SDK, no multi-touch widgets are provided. Touch event handlers are the only way for DViT table developers to program multi-touch. To implement APDT on this table, I have to use WPF standard widgets to compose the user interface, and try to use the touch event to drive the widgets.

There are two touch driven approaches are used in APDT:

1. Touch Event Handler + WPF Framework Transformation: WPF sets up a series of transformations to render visual effects, such as widgets rotation and translation. In APDT, I used SMART SDKs to receive the X Y position of a touch. "Visual hit testing" of WPF framework element is then used to find the display object on the touch position. The found object is binded with the touch. During the finger movement, new touch

positions are provided to create translate transformation on the display object. As a visual effect, the card follows the finger movements.

2. Touch + UI Automation Tool: Standard WPF controls, such as WPF buttons only respond to mouse events. To solve this problem, I used UI automation tool to create a virtual mouse object. The virtual mouse can be programmed to simulate a physical mouse device. For example, the following code simulates a mouse moving to a new position and the left button click:

```
Core.InputDevices.Mouse.Instance.Location = new System.Drawing.Point(x ,y);
Core.InputDevices.Mouse.LeftDown();
```

In APDT, I created an adapter to convert touch events into mouse events. Touch Down is interpreted into Mouse.LeftDown, Touch Move is Mouse location update and TouchUp is Mouse.LeftUp. The adapter enables using finger actions to trigger regular WPF controls.

To implement gesture control, I use Micorosoft TabletSDK that defines a set of gestures. In a PC, the SDK automatically collects a mouse movement and recognize it as a gesture. In APDT, mouse event is replaced by touch actions. Alternatively, I create an array to collect the continuous touch pointers. The touch pointers are grouped by its ID which is an identification to distinguish different touch. Once a touch up event is captured, the collected points will feed the gesture recognition engine and generate related touch commands.

Interpreting touch events into mouse events needs a lot of programming efforts. The use of UI automation tool also increases the difficulties of building and maintaining APDT. With the development of tabletop and its SDK, an increasing number of multi-touch compatible controls will encapsulate the touch handling process and provide convenient programming environment to future tabletop application developers. However, for the low-level tabletop hardware, such as DViT table, manual interpretation of touch events is still needed.

3.9 Limitations

There are some limitations coming from my system design & implementation that might hinder the use of APDT in a real-world project planning environment:

1. I used pre-defined gestures from Microsoft Tablet PC SDK. Although they provide convenience for building and maintaining the system, it is not yet known whether the gestures are “natural” and acceptable to users.

2. Concurrent keyboard typing is not supported by APDT.

3. APDT provides a card-only environment which excludes other digital artifacts such as digital documents. It simplified the APDT functional and interaction design, but might also limits its usage.

4. Present APDT is highly dependent on the multi-touch SDKs that are provided by different tabletop platforms. As a result, moving APDT to a different type of tabletop might be time consuming. In order to use advanced multi-touch controls provided by a new tabletop platform, several base codes, such as the display frameworks of digital story cards should be replaced.

3.10 Summary

This chapter presents Agile Planner for Digital Tabletop, a program which uses digital tabletops to support distributed agile planning meetings. Based on observations of traditional agile planning meetings, as well as the literature reviews of related contributions to tabletop research, APDT was designed to implement the functions for agile planning meetings. It provides multiple interactions based on the tabletop surface, such as 1) finger gesture control, 2) handwriting input, and 3) multi-touch. Telepointers are applied to guarantee that the finger movement of the participant at one location can be broadcast to every other location in the meeting scenario. Other co-located interactions, such as card operations, are also visualized by a synchronous workspace. It helps distributed participants to communicate. This chapter also provides a brief description of a user scenario where APDT is used for a distributed agile planning meeting.

APDT can be deployed on SMART DViT and FTIR tabletops. It is developed on WPF using the .Net 3.5 framework. . This chapter also shows APDT’s system architectures and its role in a complete agile project management solution. The limitations are also listed at the end of this chapter.

CHAPTER 4: CO-LOCATED EVALUATION

Agile Planner for Digital Tabletop is designed to support co-located and distributed agile planning teams. In this chapter, I will evaluate the feasibility of using tabletop for co-located agile planning meetings. I would like to know how useful APDT can be and whether agile developers feel it convenient in a co-located context. Moreover, I will look at the behavior changes when using APDT compared to using conventional tables, and then shed light on the factors that cause the changes.

Co-located evaluation is also a milestone in the APDT development process. It plays an important part to iteratively examine the development of APDT. There might be some usability issues of APDT that affect the evaluation results. Therefore, I also want to identify the usability issues, mitigate the effect of these factors in my studies by fixing major usability problems and conducting separate usability studies to expose the remaining usability issues.

In this study, two evaluation sessions were organized. The first evaluation focused on the usability aspects of APDT. Based on the evaluation of individual participants, problems that affect the use of APDT were found. Then, a student development team was invited to use APDT for their project planning meetings. They were asked to use the tabletop for their own agile planning. The group evaluation studies APDT and tabletop usage in a real-world scenario. Ethics approval for both evaluations has been granted and included in Appendix A. Combining the results of both evaluations, I want to shed light on:

- Platform Usability: Are there any usability issues in APDT that make it hard to use in a co-located agile planning meeting? What should be improved to provide a more convenient environment for agile practitioners?
- Changes to User Behavior: The motivation of my study is to use APDT for simulating the physical table-based agile planning meetings. Thus, I am very interested in how is behaviors from traditional (physical table-based) agile planning meetings changed when using APDT? In another word, although tabletops and physical table are both horizontal surface, whether planning behaviors observed on physical tables are still observable on tabletops and how they change. More important, what factor(s) leads to the change(s).

4.1 Individual Evaluation

4.1.1 Goal

This part of my study is conducted to fulfill two main goals:

(1) Finding out the major usability issues of APDT.

(2) Help improving the design of APDT so that it could be better prepared for the following group evaluation.

4.1.2 Methodology

The evaluation was held in a controlled environment, in which a sequence of activities was assigned for the participants to complete individually.

Pre-questionnaire: Prior to conducting any task with APDT, participants were asked to fill in a questionnaire form (see Appendix B) to collect information about their familiarity with agile planning tools, agile project planning, and the hardware of digital tabletops. This questionnaire aims at identifying the participants' knowledge level and hardware familiarity. Moreover, based on understanding the participants' skill levels, I can arrange an appropriate briefing and training session before the formal evaluation to guarantee the participants possessing enough knowledge for participating in the evaluation. The pre-questionnaire helped categorizing the participants into different user groups, such as skilled users and inexperienced users. The categorizations increased the practical value of the evaluation. The results of this questionnaire are described in Chapter 4.1.3.

Briefing and training: Before the evaluation started, participants are provided ten minutes training. The training first covers the basic terminologies of agile project planning, such as "story card", "iteration" and "backlog". The briefing session is arranged to ensure that all the participants are familiar with basic agile planning terminology, so that the evaluation results will not be affected by the knowledge level of the participants. The training session also helps participants to understand the basic functions of APDT and the gesture definitions illustrated in Figure 3-5. Moreover, every participant is allowed to use 3 to 4 minutes to interact with the tabletop. This helps the participants, particularly those who had never used touch devices to overcome the nervousness of using the digital tabletops. During the training process, the participants are free to ask any questions about the tabletop usage. However, the briefing and training is organized individually. I arranged separate times to run the evaluation with different participants. The arrangement is to avoid passing knowledge and skills between the participants who had already done the evaluation and those who were new to the evaluation.

A task-centered study is used in this evaluation. I chose to use a task-centered study for the reason that many participants may not be familiar with the APDT tool. Due to this, if no tasks are specified, they may not know of (and in turn, may not make use of) certain functions, which respectively, limits the quantity and quality of data that I can evaluate. In terms of task-centered study, the participants' behaviors are controlled to guarantee an evaluation of APDT's complete functionality. From the other side, the tasks play a role of a brief guideline that helps participants deciding what they are going to test.

The tasks were listed in a single page script that consisted of 15 clearly numbered task. It is shown in Appendix C. The tasks were designed to cover the following aspects:

1. The interface design of the tool: Whether functional widgets and digital artifacts are easy to use. It will be evaluated based on Likert-scale questionnaire and my on-site observations.
2. Learnability: Is there any problem of learning to use APDT? Particularly, are the features such as finger gestures easy to be accepted by participants? The factor can be exposed by interviewing participants.
3. Usability of gestures: Finger gestures are a new interactive approach provided by touch surfaces. It is not yet adopted by other agile planning tools. I would like to investigate how well it is accepted and used by the participants. This can be uncovered by a questionnaire study and observations.
4. Accuracy of handwriting and speech recognition: Handwriting is a conventional input approach and speech recognition is computer-based feature. Both of them

will be evaluated in the context of APDT. For handwriting, I would like to reveal the user satisfaction of using finger or stylus-based handwriting and uncover some potential usability problems. Speech recognition is rapid, intuitive and easy. However, the effect of using it still needs a careful investigation.

5. System performance: Evaluate, particularly observe whether there is any system delay or interface lags.

For complex tasks that are composed of sequential operations, some hints were given at the bottom of the tasks to give the participants a starting point. The hints were carefully revised to give clear, necessary, and minimal amount of help. I expected the hints to protect the participants from being obstructed by the unfamiliarity with APDT usage. An example instruction is shown as follows and all the instructions are shown in Appendix C.

The card can be tossed on the surface of the screen

During the task-centered study, the participants are encouraged to ask questions when they encountered problems. However, I will determine whether I would answer some question so that unnecessary help will not be given to distort the evaluation results. All the questions in this process will be carefully recorded, as they might reflect the problems of participants when using APDT and digital tabletop.

Observation: An essential part of my evaluation is to observe the users' operations in the task-centered study. I was interested in participant's satisfaction, behavior, reactions and comments when using APDT. The participants were encouraged to "think aloud" while doing the tasks. That is, they were asked to speak out what they wanted to do and how they intended to do it. They were also encouraged to ask questions whenever they needed; however, I used caution when providing answers to make sure not to bias the subject's perceptions. In the observation process, I will ask questions when I found the participants are confused, or obstructed. The typical questions is "what are you thinking?", "what are you looking for?" or "is there any problem?" Another important role of observations is accumulating potential question that I can ask the participants in the following "informal interview" session.

Post-Questionnaire: At the end of the evaluation, participants were provided with a questionnaire (see Appendix D) to collect information on how they perceived the tool. The questionnaire consisted of Likert-scale questions as well as open-ended questions to give the participants a chance to express their opinions. The Likert-scale questions cover major functionalities I would like to evaluate, such as the use of finger gestures, the real-time performance and handwriting. They also facilitate the evaluation of user preferences to APDT or traditional meetings, as well as the users' satisfaction with APDT and the digital tabletop. The open questions brought some interesting answers and valuable comments that represented the users' real experience and ideas of using APDT.

Informal Interview: Some participants who were observed to have difficulty or that took a relatively long time to finish the tasks were informally interviewed for no more than 10 minutes to get more information on what was hindering their performance. Interesting comments or suggestions from participants were also discussed in this session to uncover the reason for the comments. Another important task is to clarify some confusions or unexpected behavior of the participants, exposing the factors that triggered them. The example question is shown as:

Why you looked confused when using your finger writing on the card?

4.1.3 Participants and Environment

The usability study involved 14 participants; all were graduate students in computer science. Participation was voluntary without receiving any payment. Evaluation sessions were scheduled at the convenience of both the participants and the observer. Participants were asked to come to the lab at different times to individually conduct the evaluation. This avoids any learning effects among subjects. Each participant was given the choice to stand on any side of the tabletop; whereas the observer stood on the opposite side.

Based on the pre-questionnaire participants that were given prior to the evaluation, 9 subjects had a general idea about agile methods. Three of which had actually used agile methods to develop software applications. The remaining 2 participants needs detailed explanation of agile project planning.

Regarding knowledge on digital surfaces, 7 out of the 14 subjects had seen digital surfaces before, mainly on TV or on the Internet. Four of which had used a tabletop once or twice. 10 of the 14 subjects had used other touch sensitive devices such as tablet-PC's and SMART boards.

The evaluation environment used the SMART DViT table. However, a conventional keyboard and a mouse are still provided, so that the user preferences regarding keyboard or finger interactions can be observed. A microphone is placed on the tabletop to allow for voice control. The whole process is observed by me. No audio or video recording device is used. Finger 4-1 illustrates the basic layout of the hardware setting.

Observer

Participant

Figure 4-1: Environment of Co-located Evaluation

4.1.4 Evaluation Process

The usability evaluation started up with a *pilot study*. The pilot study had two main objectives:

(1) To give early insight on the design of the study in general, and

(2) To discover major usability issues and fix them before conducting the rest of the individual study and the group study.

The pilot study involved 5 subjects. These subjects underwent a procedure similar to the one explained in the methodology session. The outcome of the pilot study encompassed

(1) A set of major usability problems and bugs to be fixed,

(2) Suggestions to improve the task list and related instructions (Based on their suggestions, the task list and instruction are improved and shown in Appendix C), and

(3) Possible improvements to the questionnaires.

Usability issues were observed in tasks such as deleting artifacts with gestures (it needed many attempts to get it right) and resizing artifacts using finger touch. Also, some usability problems were related to performance issues that resulted in a slow reaction from the tool to the users' commands. Moreover, a general usability issue was the over-sensitivity or inaccuracy of the digital surface reaction to the users' touch. Figure 4-2 shows the results of the pilot study. The number in the circle indicates how many participants rated the task at a certain level of easiness. For example, the number of participants who thought "*using help*" was an *average* task is *3*.

After the pilot study, I resolved performance/usability issues and fixed some bugs. I increased the size of controls to offset the position error caused by the inaccuracy of the finger touch. The change is based on the observation that participants felt their fingers too thick to touch a small point. The digital tabletop was recalibrated to get a better performance of touch positioning. The deletion gesture was commented hard to use. To solve the issue, a delete button on the corner of the artifact was added as a complementary approach. I also provided a larger handwriting enabled space in response to the evaluator's comments.

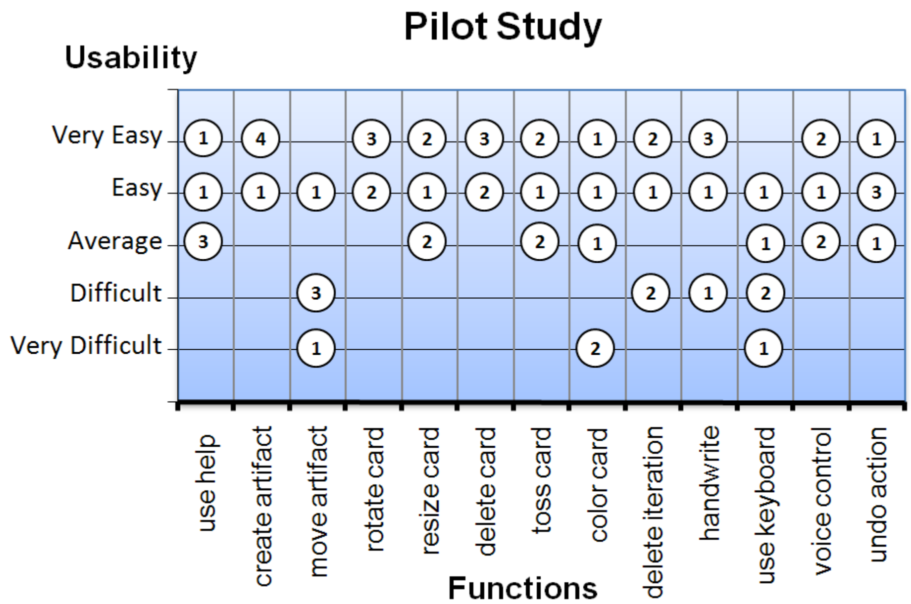

Figure 4-2: Pilot study results

The pre- and post-questionnaires were both refined iteratively to provide more reliable and valid question items. Furthermore, the wording of some tasks was modified and the instruction set (Appendix C) was changed accordingly.

The formal evaluation was conducted after finishing the changes to APDT resulting from the pilot study. In this evaluation, the remaining 9 of 14 participants were required to go through the refined procedure and fill out the questionnaires. Some participants were also interviewed.

Figure 4-3 shows the questionnaire results the same way as in Figure 4-2. Compared to the initial results from the pilot study, the formal evaluation clearly reveals a better usability of APDT. It is noticeable that participants' votes are highly concentrated above the average level of easiness except for the handwriting feature.

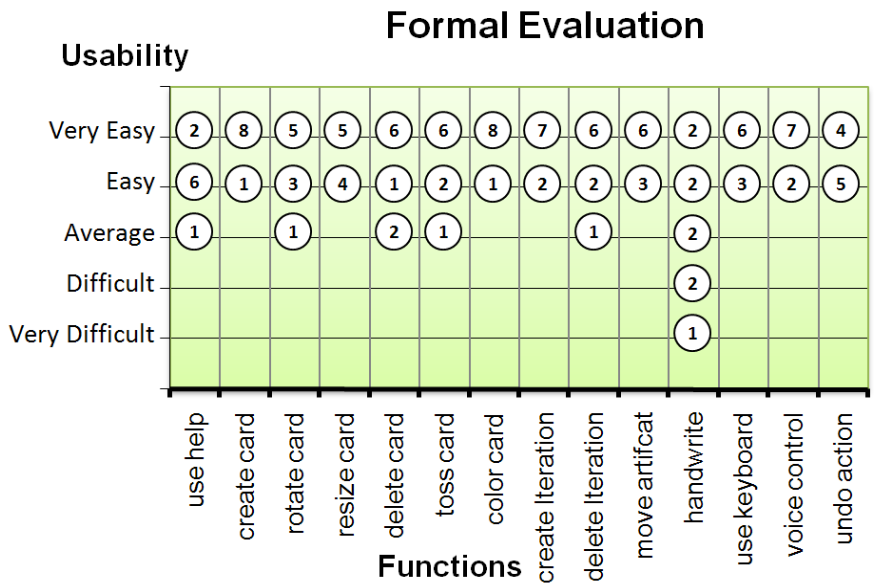

Figure 4-3: Formal evaluation results

Most of the tasks were commented as easy. Nevertheless, three participants showed their dissatisfaction with the handwriting functionality. The informal interviews with them revealed that they felt the handwriting on tabletop was too thick and hard to recognize.

According to the observations, in the pilot study, the participants asked on average one question per subject - questions like: *"How can I do that?", "Why does this not work?", "Is it right to do it like this?"*. In the formal evaluation; however, only 3 similar questions were asked by all participants.

The formal evaluation also revealed user preferences on the functions and interactions of APDT. The results show that 4 of 9 participants prefer gestures while 5 others prefer voice control. 3 participants prefer using handwriting as opposed to using keyboard.

During the evaluation, a mouse was intentionally put on the table to observe participants' reactions. Interestingly, while in the pilot study some participants used the mouse as opposed to their finger tips to interact with the tool, few participants in the formal evaluation used the mouse to complete the evaluation tasks. Some participants even considered using their finger tips "*much more flexible than using a mouse to click*".

By the end of the individual evaluation, a conclusion can be drawn that both reliability and usability of the system were significantly enhanced by the changes. However, some issues like handwriting and two-touch limitation were still seen as hindering. This fact is to be considered when analyzing the results of the group evaluation.

4.2 Group Evaluation

Agile planning meetings are conducted by a group of participants. Although the individual evaluation provided usability feedbacks, the real use of APDT is still required to be tested in a group environment. In this evaluation, a student team is invited to use APDT for their planning meetings. The evaluation is conducted in the lab environment. But the topics of meeting are decided by the team based on their development tasks. The duration of the agile planning meeting is determined by the subject team, not the observer. In summary, this evaluation is designed to employ the lab environment but using the real development efforts of a student agile team. The whole meeting process was observed by the evaluator.

4.2.1 Goal

The goal of the group evaluation was to explore the different aspects of using a digital tabletop in co-located agile planning meetings and study its usefulness. Moreover, the conclusions of individual evaluations will be further reviewed by the group study.

4.2.2 Participants and Environment

A five member agile team working together in one environment was the target of my observation. All members have conducted agile development for several months and thus possess hands on experience in agile methods. Since all participants were working in agile software engineering laboratory where the tabletop was, they all had a good idea on how to use the tabletop. Thus, the training was focused on the functions of APDT. This familiarity with the tabletop is unlikely to introduce any bias because the team has never used APDT for planning purposes before this evaluation. The hardware setting of group evaluation was still the SMART DViT table at the agile software engineering lab.

4.2.3 Methodology

The evaluation is conducted in a qualitative way. This qualitative study depended on observation and retrospective interviews. In this section, I will explain how these two methods were employed to help me reach my goal in investigating the feasibility of utilizing the digital tabletop tool in agile planning meetings.

Observation: The observational sessions were held on a biweekly basis. Each observation is based on the agile planning meetings of the team. Thus, the schedule is determined by the subject team. A total of 4 evaluation sessions are conducted. The first two evaluations are held based on pen and paper meetings and the following two sessions are on tabletop-based meeting. While observing the traditional pen and paper meetings, I was looking at typical collaborative activities and practices the team had to go through during the meeting. This was especially important for the study to make solid comparisons between the traditional setting and the electronic setting. When observing the electronic setting, I was interested in observing the activities of participants. Moreover, the face to face communication and the opportunity of collaboration amongst attendees were both important aspects to look at. Positive and negative comments were of equal interest to my study. Although the agile planning meetings are conducted in a lab environment, the participants used their own development tasks and all the output of the meetings was useful to their future development. Before starting the meeting, participants were told that they would be observed by me for studying the use of APDT. They were also informed that there was no video or audio taping.

Interviews: At the end of the four observational sessions, 10 minute formal interviews were conducted individually with the members of the agile team. They were asked open-ended questions (like the ones in the box below) to freely express their opinions about using the tabletops as a means of conducting the planning meeting. Some questions focused on a direct comparison between what they used to do in paper and pen-based meetings as opposed to what they did in digital tabletop based meetings. The objective of these questions was to understand how the two methods (pen-paper vs. tablteop) differ from each other and in which situations one would be more practical than the other. Another set of questions focused on the use of gestures, handwriting, and voice commands for they were the newest features in the tool. Some sample interview questions are provided as follows:

1. What changes do you think using a digital tabletop posed on your planning meetings?
2. What do you like/dislike most about APDT?
3. If you were given the choice, would you prefer to use the tabletop or pen and paper in the next meetings?
4. Was there any advantage of utilizing a digital tabletop in your planning

User comments from these interviews will be reviewed. I will highlight some statements that are related to the changes of their habits or experiences. The results are shown in Table 4-1.

4.2.4 Group Evaluation Process

I observed four co-located planning meetings, 2 of which utilized tabletop. Each meeting took on average about 45 minutes. The five attendees plus one observer were seated around the table. The observation process was neither interrupting nor intrusive. As mentioned earlier, since I was observing a team that was originally working in the same laboratory with me, my presence as an observer was transparent to most of the participants. After the series of meetings I attended, I started to conduct formal interviews with participants to solicit as much information as possible. As per consent of the interviewees, the interviews were audio taped for qualitative analysis.

4.3 Results

My analysis focused on the interviews following the group evaluation. The transcripts qualitatively show the practice of using digital tabletop for co-located agile planning meetings. The analysis results of the transcripts will shed light on

(1) the changes of traditional practices (behavior observed while participants conducted physical table-based agile planning meetings),

(2) the factors that affects the changes and

(3) how APDT can be improved based on this usability evaluation.

4.3.1 Changes of Traditional Practices

In the interview, the participants reported some changes of their natural behavior while conducting a tabletop-based co-located planning meeting. Table 4-1 highlights critical statements from the interviews.

Table 4-1: Comments related to changes in traditional practices

C1	It is almost the same. The only difference is that traditionally, you can grab the physical card and give it to someone in the hand, but on the tabletop, everything is on the surface.
C2	In paper based [meeting], the story card is too small. You have to pass it around to people one by one so they can see it. On the tabletop it is big enough for everybody to look at it at the same time.

C3	In the pen-paper planning meeting, everybody can write story cards at the same time, but APDT allows only one person to write at a time.
C4	I used keyboard to write on the story card, because the handwriting on the tabletop is hard to recognize.
C5	It is not that I don't like speech [voice control] but it is not quick. I had to say three times "create story card" before it actually did. Finger tip control; however, is much easier.

As the table shows, some participants found the way of working in agile planning meeting had been changed. In a tabletop-based agile meeting, all of the cards are virtually displayed on the table surface but not all the attendees are allowed to interact with tabletop at the same time. The basic reason for this is that the digital tabletop we used for evaluation can only support two simultaneous touch actions. Additional touches will be ignored if there has been already two touches detected by the tabletop screen. However, in a pen-paper based agile planning meeting, every attendee can operate cards concurrently. They can fill out a card, passing or throwing it without interrupting other developers, without being hindered by used up touch points. Moreover, although the DViT tabletop provides a thick border to place keyboards, documents or other stuff, the meeting attendees might accidently put some physical objects, such as pens or documents on the table surface. Using our tabletop, these physical objects will consume a touch point, thus finger touch of user are sometimes blocked. To interact with a tabletop, a participant must check whether the touch has been used up, particularly whether too many objects are touching the table surface. This process hinders the meeting process and causes dissatisfactions with APDT. However, the dissatisfaction can be resolved by increasing the maximum number of recognizing concurrent touches, such as replacing the DViT table with other tabletops.

Using handwriting to fill out a story card is a conventional input behavior observed in a pen-paper based planning meeting. For APDT, I developed a handwriting function to support handwriting input on the tabletop. However, the use of handwriting for editing story cards was rarely observed in group study. The participants would prefer using keyboard input which is "unnatural" for a traditional meeting rather than using finger tips to do handwritings. Interviewing the team members provided some reasons that cause the user preferences. The participants felt it uncomfortable to write directly on the tabletop surface with their fingers. One participant mentioned that *"my finger is too thick to write some small stroke clearly"*. Moreover, the keyboard usage is regarded "*natural*" in a computer environment. One participant explained that *"I always consider the tabletop a computer with a big, horizontal screen, so looking for a keyboard is always my first choice"*.

Another change to the traditional practice was introduced by the speech recognition feature. Traditionally, in agile planning meetings, collaborators use their hands to manipulate paper artifacts. In APDT, however, voice commands were introduced as another approach to control artifacts. My observations revealed that the attendees did not often use voice control although they considered this option *"cool"* and *"amazing"*. The interviews exposed that the main reason behind not accepting this change is that participants perceived the voice control as unreliable as indicated in the C5 of Table 4-1. Participants, especially those who were not English native speakers, needed sometimes to repeat their voice commands several times to get a response from the system. Even when they got a response, the system sometimes responded unexpectedly. The conclusion is different from the results of individual evaluation, in which 5 participants would prefer using voice command. The differences of results might be caused by the changes of environment. In the individual evaluation, only one participant uses voice command and no discussion happened. Therefore, the voice command is clear. However, group evaluation mixed the voices of several participants and hinders the recognition of voice commands.

The last point to mention in this context is that when observing the meetings, I noticed that the tabletop added a “fun” attribute to the meeting activities. This was more obvious when doing things like throwing a card to a collaborator at the other end of the table, or rotating a card to a collaborator on the opposite side. Over the series of meetings I have attended, I repeatedly heard things like “This is fun” and “That is cool”. Although I don’t expect this “fun” factor to last for long, I could tell that it can be a basis to encourage fun interaction in the meeting and strengthen bonds amongst team members.

4.3.2 Factors that Affect Behavior

The above study described changes on user behavior while comparing using the digital tabletop with using a physical table to conduct a collocated agile planning meeting. Some of the changes were welcome and even perceived as constructive; whereas others were perceived negatively. In this part, I list three factors that affect participants’ attitudes to the changes. The factors are proved by the evaluation results. I expected the factors retrieved from the evaluation will guide the future design of tabletop-based agile planning tools.

1. Parallel working

Parallel working is naturally observed in physical table based agile planning meetings. Although the multi-touch for tabletops is to inherit parallel working from physical table-based collaborations, our DViT tabletop which allows only 2 concurrent touches hindered this feature and thus, caused some negative comments to the tabletop-based meetings.

2. Responsiveness

Responsiveness is defined as how fast the system responds to the users' commands. Responsiveness played an important role in determining the usability of the tabletop in agile meetings. Responsiveness is not a problem for conventional physical table based meeting, in which a computer is absent. However, for tabletop agile planning meeting, it is noticeable. Since an agile planning meeting is a dynamic activity during which group collaboration is strongly encouraged, poor responsiveness of the system might hinder or delay the interactive processes. This hindrance was very noticeable in the agile planning meetings I attended, and was explicitly mentioned by some participants as a source of disturbance. The voice command, for example, is commented that sometimes it does not provide any response. As a result, some participants felt confused and frustrated (see C5 in Table 4-1).

3. Simplicity and Accuracy

Users' preference is strongly influenced by the simplicity of the interaction and the level of accuracy needed to accomplish this interaction. Users tend to value simple and reasonably sensitive operations over complex or oversensitive ones. According to Nielsen et al. [Nielsen & Norman, 2000], simplicity is an essential component of user experience. This was the case in our study even when the complex alternative was perceived as "fun" or "natural". For instance, using handwriting on digital tabletop is a natural extension of using a pen to write on paper story cards. Nevertheless, participants were more likely to use a keyboard because it was simpler and did not demand accuracy, whereas handwriting was a complex process that involved multiple steps. And due to the unnatural thickness of the electronic marker's tip, the user was required to be accurate when using the electronic marker to write contents

4.3.3The Design Experience from Co-located Evaluation

Pen-paper and physical tables dominate present co-located agile planning meetings. Although digital tabletops and APDT improves the co-located meeting process by automatic saving and exchanging card information, it is unlikely that pen-paper based meeting will be replaced in the near future. The reasons are shown as follows:

Cost: Present digital tabletops cost thousands of dollars. A pen-paper and physical table will be more economical for the foreseeable future.

User habits: Using pen-paper cards maintains the users' common behaviors that have been established in their daily lives. There is no proof that pursuing a new technology will be the more attractive than maintaining an already-existing and convenient habit (unless the habits are no longer available due to the changes of environments, such as moving to distributed work processes). Wallace's theory (see Chapter 2.2.1) also indicates the advantage of traditional agile planning meetings. He mentioned that simplicity of interaction and familiarity to an interaction object helps reducing the social pressures in a formal activity.

Shortcomings of Tabletops and APDT: Chapter 4.3.1 lists the results that several users felt their traditional behaviors were changed by using APDT. Amongst the user comments, several negative points should be highlighted. For example, users found they cannot concurrently operate the cards due to the limited amount of touch points from the DViT table. They noticed several issues that were never found in traditional agile planning meetings, such as using some gestures but getting no response. They also found that using digital tabletops for handwriting is not an intuitive experience. The negative effects of tabletops and APDT would likely prevent users from selecting tabletops for their co-located meetings.

However, the evaluation of using tabletops for co-located agile planning meetings is still valuable because it provides lessons to improve APDT. The lessons and experience from the development of the co-located version will help developing the versions for distributed settings. The experience is shown as follows:

1. An inappropriate gesture definition will be confusing and significantly affect the user experience.

2. Speech control is "cool" and "fun" in single-user usability studies but not applicable during a meeting. A typical example is, when participants discussing whether they should

create a story card, a new card might have been created because the speech command "create story card" was recognized by the system.

3. Touch is not a simple replacement for a traditional mouse device. A finger touch is not as accurate as mouse pointer, thus, it is important to carefully design a UI widget (such as, its size) to remove the "Fat Finger Effect" which is not observed in the use of mouse pointers.

4. The evaluation participants are possibly positively biased by tabletop technology as it is considered to be "cool". Their "coolness" experience might provide biased statements thus misleading the evaluation results.

4.4 Limitations

Although the design of the evaluation was refined after the pilot study to make the results valid and reliable, the results are yet to be generalized on a large scale. First of all, a more longitudinal study is needed to eliminate the "coolness" factor that may have biased the participants' reactions towards the new tool. Also, more teams are to be observed before I can make solid generalizations about the practicality of the tool in agile contexts. Another limitation that might affect the evaluation is the selection of participants. The participants that attend individual evaluations are voluntary. They are not randomly-sampled so that I might lose the comments from some parts of potential APDT users, such as agile developer who is over 40-year old. The team that attended group evaluation is composed of students. Their approaches of using APDT and organizing agile planning meetings might be different from the real-world agile development teams.

4.5 Summary

A variety of solutions have been proposed to enhance agile planning meetings through the use of electronic devices. While some solutions are unable to provide sufficient coverage of all practices required in the meeting, they often introduce disturbing changes to the original setting of the meeting. My proposal is to employ digital tabletops in agile planning meetings for co-located teams resulted in the development of Agile Planner for Digital Tabletops.This chapter aims at

1. Improving the usability of APDT and

2. Finding out the changes to user behaviors as well as factors that affects the user behaviors, and

My approach was evaluated through two different yet interrelated studies. The first study aimed to look at the usability of the tool, and the second study aimed to look at the usefulness of the tool in agile contexts. After improving the tool design, I reached to a promising usability level. Study subjects were quickly able to learn how to interact with APDT and accomplish their tasks. Yet, there still are some usability issues, especially related to handwriting support. The group study which involved a student agile team over a series of planning meetings showed the use of tabletops in a practical agile planning meeting. Based on the group study, I summarized the behaviors that have been changed due to the use of tabletop. The factors that cause the changes are also listed.

Although a tabletop is unlikely to be used in a real-world agile planning meeting (see Chapter 4.3.3), the study still played a positive part in refining the interface design of APDT and showing some design experience that might help the future development. At the end of this chapter, the limitations of the evaluation are listed.

CHAPTER 5: EVALUATING THE DISTRIBUTED VERSION

Distributed agile development is moving to the mainstream of agile software engineering. A spatially separated agile team requires effective support by project planning tools. My literature review has revealed that present agile planning tools are mostly based on vertical displays. Although they provide some distributed features to communicate agile teams, they are not as effective as a physical table when organizing group collaborations. Digital tabletops might be an applicable device for distributed teams. In this chapter, I will describe the evaluation of using APDT to support distributed agile teams.

5.1 Evaluation Goal

This evaluation is organized to answer the following questions

- Whether tabletops support distributed agile project planning.
- How tabletop design (FTIR and DViT) impacts distributed collaborations in the context of agile planning meetings.

Based on the literature review in Chapter 2.2.2, I anticipated observing some issues that will be caused by the functional limits of FTIR and DViT tabletops, such as the lack of user identification and virtual arms. However, this would not necessarily indicate their insufficiency for distributed agile teams. In order to explore the usefulness of tabletops for multi-group agile planning meetings, I will answer the first question by observing distributed planning meetings.

Answering the second question might provide some experience for developers of tabletop hardware technologies. At present, digital tabletops are widely applied to support co-located, single-group activities. Using tabletops for distributed, multi-site collaboration is rarely observed. Therefore, distributed agile planning meetings might be a good context to observe the real-world usage of distributed tables. To address this question, I will use observations of the user interactions with two different, connected tables and cautiously organize the findings to avoid making biased, over-generalized conclusions that may mislead tabletop researchers.

5.2 Evaluation Settings

5.2.1 Evaluation Participants

Ten voluntary university students attended our evaluation. All of them have general experience of using agile methods to develop software. Participants each received $20 as compensation for their time. Ethics approval has been granted and included in Appendix A.

I briefly interviewed the participants to understand their background on agile planning and their relations with each other. The results show that among the ten participants, three master students are from agile software engineering lab. They often attend agile planning meetings during their daily work. Another four participants are 2 PhD and 2 master candidates. Although not from the same team, they enrolled in a graduate level, agile software engineering course, on which they were organized into a project team to practice agile development. The remaining three participants are 3^{rd}-year undergraduate students who have some experience of agile project planning from their courses. None of the participants attended my co-located evaluation. According to my background survey, I decided to divide the undergraduate students into separate distributed teams so that the teams in the evaluation are mixing inexperienced and experienced members.

5.2.2 Software & Hardware Settings

I improved APDT to support this study. APDT allows for multiple concurrent interactions with the digital tabletops. It implements multi-finger touch and mouse event response, gesture recognition (using a finger to draw strokes on table surface and strokes with specific shapes will be recognized as commands), and handwriting recognition to support agile planning interactions, such as creating, deleting, moving, rotating, editing and prioritizing story cards in iterations.

To support my distributed study, telepointers and a shared workspace is provided by APDT. Telepointers show finger movements on the other table. The actions of telepointers are synchronously broadcasted to every other tabletop at different sites. The APDT interface is also updated in real-time to show the user operations from every connected tabletop.

I prepared two separate meeting rooms to simulate a geographically separated

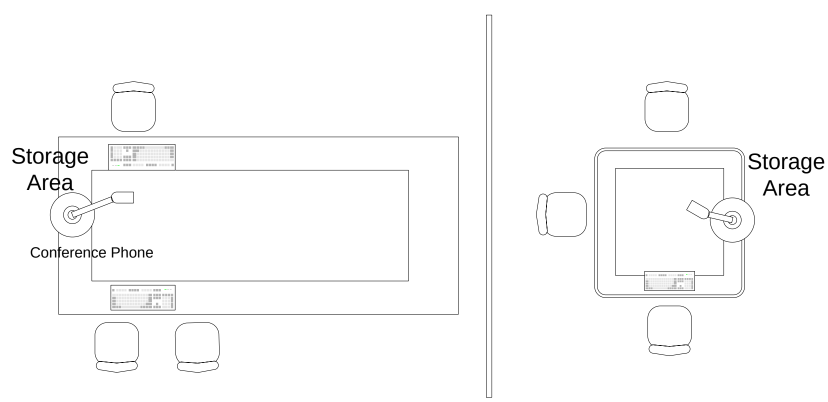

Figure 5-1: Layout of experimental sites

environment (see Figure 5-1). Two evaluation sessions were organized. In each session, an agile planning meeting conducted. The first meeting involved two groups. Each group consisted of 2 people. The second session involves another 2 groups with 6 participants (3 in each group). Each the subjects participated in only one meeting. Every meeting room has a tabletop. In the planning meetings, each group stays with its own table. None of them switch between the two different tables. To support verbal conversations, I set up conference calls by using Skype (see Figure 5-2).

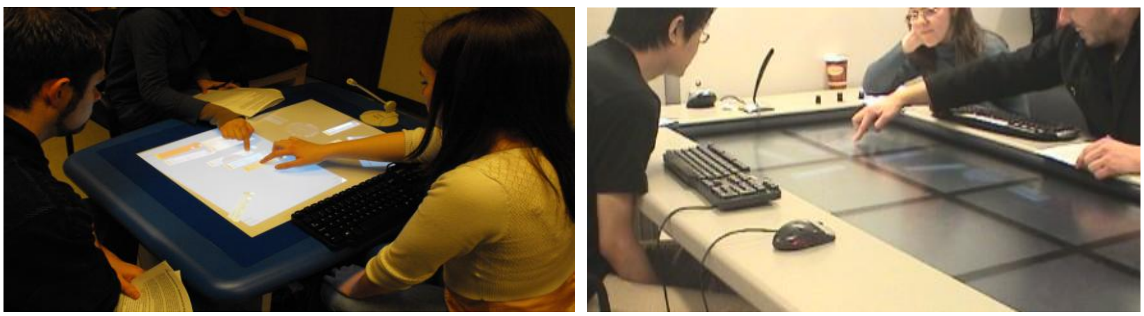

Figure 5-2: Distributed evaluation

One DViT and one FTIR tabletop are used to support the distributed evaluation. The descriptions of both tables have been included in Chapter 2.2.2. DViT and FTIR tabletops provide a tangible screen to support touch-based interactions. However, in order to investigate the user preferences of interaction mechanisms (keyboard vs. handwriting, mouse vs. finger touch), keyboards and mice were provided, too.

5.2.3 Experimental Task

The subject teams were required to plan the development of an ATM application for a bank. They were placed at the beginning of the project and had to determine how to start up the project. The goal of the planning meeting was to create a set of tasks that the team would be working on in the first development iteration. They should discuss the future development plans, the selection of programming languages, and the choice of software testing servers. Since various basic, but important decisions would be made in the planning meeting, I had plenty of chances to observe how tabletops were used for supporting multi-group interactions.

5.2.4 Evaluation Process

The evaluation consisted of a sequence of activities:

Training: Prior to starting the evaluation session, the evaluator and participants spent 20 minutes to go through the basic functions of APDT and the digital tabletop. The participants are allowed to touch the tabletop and practice some basic operations of APDT. Questions about the use of APDT are answered in this session. Meanwhile, the evaluator confirmed that the participants were familiar with the basic terminologies of agile planning, such as “iteration” and “story card”.

On-site observation: An essential part of my evaluation is to observe the user behavior and conversations while having a planning meeting. The evaluator sat at one site to observe participants actions and body gestures. Meanwhile, the other site was recorded by a video camera. For both evaluations, I sat at different rooms so that the use of DViT and FTIR tables can be observed. My intent was to find interesting behavior or conversations, which might be important indicators of the participants’ awareness of group collaborations. Unexpected usability problems of APDT are also recorded for improving our tool. During the evaluation session, I tried not to interrupt participants. Comments or unnecessary distractions were avoided to protect the participants’ meetings from being disturbed. However, as the participants might not be familiar with the use of APDT and tabletops, some help will be given if they felt confused with how to use APDT for supporting a specific interaction, such as minimizing story card. The questions and confusions were carefully recorded for our further analysis.

Onsite Observation is combined with the subject meetings. In the meetings, the participating teams decided when they finished the assigned task. The first meeting involved 4 participants and took 15 minutes while the second meeting involved 6 participants and they spent approximately 20 minutes. The outcomes of the planning meetings were adequate for the assigned task. For group A and B, a total of 10 and 9 story cards are created for the first iteration.

Video recording: Video recording complements the onsite observation. I recorded participants' actions, conversations, body gestures and their discussion process. The rich information captured by video recording and my observations provided the basis for analyzing tabletop usage in a distributed team. Moreover, using video recording helps in reducing the burden of on-site observation. I can review the meeting process and uncover some interesting phenomena afterwards by replaying the videotapes. That helps me to capture many useful insights from the evaluation process.

Questionnaire survey: I designed a questionnaire form (see Appendix D) to collect participants' comments on APDT and digital tabletop. The questionnaire consists of Likert-scale questions. It uses to analyze the usability of APDT and tabletop based on an ordinal measurement. The questions concentrate on basic functions and interaction features of tabletops and APDT.

Interview: A ten-minute interview is conducted after the evaluation session. The interview is organized based on group, rather than individual. Some participants, especially those who had difficulties when using APDT are requested to provide more information on what hindered their performance and/or communication with others. Moreover, questions such as “How would you improve APDT?” are asked to encourage participants to share their experience and novel ideas with the evaluator.

5.3 Results

In this part, I present the results from the distributed experiments. The results combine the questionnaire survey, interview and observations. They discuss the output of meetings, territoriality and orientation on distributed tabletops, interaction with the planning tool, the intra- and inter-collaborations, which will be used to analyze the feasibility of using tabletops for distributed agile planning meetings.

5.3.1 Output of Agile Planning Meetings

Output is an important factor to indicate how effective agile planning meetings are conducted [Karolak, 1998]. The interviews show that both groups are satisfied with their output. They comment that the goals of their planning meetings have been reached and the team understands which tasks need to be accomplished in the next development iteration. Moreover, the share workspace solved the card inconsistency which was observed in physical table-based teleconference [Morgan, 2008].

5.3.2 Interactions with the Planning Tool

In this evaluation, I investigated user preferences on using finger touch or mouse, handwriting or keyboard, and the users' attitudes towards finger gestures.

Finger touch vs. mouse: 8 out of 10 participants would prefer using finger touch and the remaining 2 choose mouse. In detail, 7 participants felt using finger touch "easy" or "very easy". 2 participants considered "average" and only one felt it "difficult". Many participants commented that using finger touch was flexible. One subject said: "*It is better to use finger so that I'd only switch between keyboard & table rather than switching to mouse as well.*" In our evaluation sessions, only 5 mouse clicks were observed in total during 35 minutes of meetings. They happened when users wanted to touch a small button or activate a text area to input text.

The "fat finger effect" [Ghanam, Wang, & Maurer, 2008] still hinders users to touch small widgets or draw thin strokes on the table surface. This happened on both FTIR and DViT tables. Some participants commented it was difficult to touch a small widget by using their fingers.

Handwriting vs. keyboard typing: Participants clearly showed a preference to use a keyboard for text input on both DViT and FTIR tables. Although all the participants are trained to use handwriting input before the planning meetings, only 2 attempts at using handwriting are observed in our studies – and both failed. Oppositely 22 times keyboard input are observed. Moreover, I collected some user comments indicating that using keyboard is a natural interaction for participants. One participant commented: *[A keyboard is a] common method for text entry, most people are now accustomed.*

In commonly used operating systems, keyboards cannot be used for concurrent input as there is only one widget that receives text input at any given point in time. I assumed that users would negotiate the privilege of holding the keyboard when they would like to use it. However, our observation reveals that the participants did not bother changing the control of keyboard. The person who is sitting nearest to a keyboard is automatically taking on the duty of typing information for the whole group. I did not find two co-located participants grabbing a keyboard at the same time or typing on the same card at the large DViT table where two keyboards are provided. I did not observe distributed groups concurrently typing on the same story card either.

Finger gestures: 5 of the 10 participants considered gesture "very easy" to use, while 3 commented it "easy". One subject indicated: *[gestures are] a great tool to make the interface easy to use and fun.* However, among the 5 FTIR tabletop users, 3 reported their difficulties of using some gestures that require several steps or long strokes, although other gestures show their conveniences and one of the 3 participants commented it easy to use. The users commented "*the lines are always broken for some reasons*".

I summarize the Likert-scale questions about the user preference on keyboard/handwriting, finger touch/mouse and the use of gesture controls. They are shown in Figure 5-3.

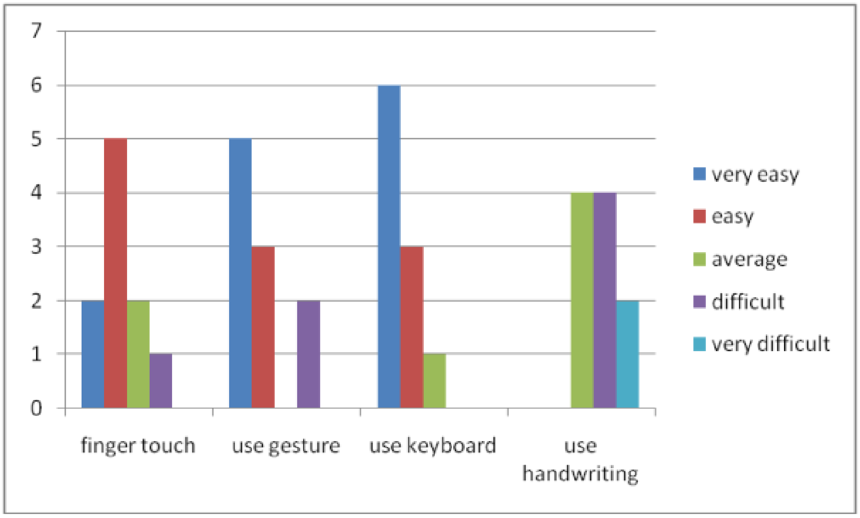

Figure 5-3: Questionnaire results

Remote gestures: The questionnaire survey reveals that 9 of the 10 participants say "Yes" when they were asked whether they feel OK without watching gestures drawn by remote participants. My observations provide complementary evidence to the result. They indicate that unable to see the gestures drawn by remote teammates does not hinder the planning process because they can still realize a card is created, deleted, edited, or moved. The participants also commented they would like to see remote finger gestures just like they watch the finger gesture of co-located teammate and this makes them feel the presence of their distributed colleagues.

5.3.3 Territoriality on Distributed Tabletops

Three types of territories are used by participants. The edge of the tabletops becomes a storage territory. It stores physical objects such as keyboard, microphones and personal belongs. The DViT table is welcomed as it provides a large space to put participants' paper materials and arms. The FTIR table provides limited storage space and participants must hold their paper documents all the time. Personal and group territory is used for digital objects. I found personal space created when participants dragging and reorienting cards to their side of the table. Towards the end of planning meetings, the personal territory is abandoned and the group territory dominates the table surface. All the cards were sorted and grouped at the center of table surface (Figure 5-4).

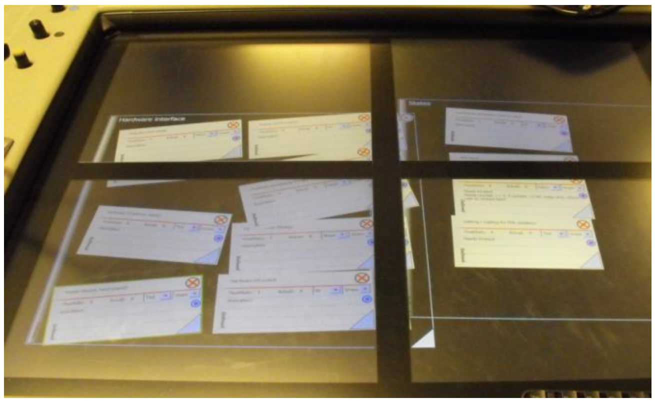

Figure 5-4: Output of agile planning meeting

5.3.4 Intra-group Collaborations

Collaborative interactions within the same site (intra-group) are often observed in this evaluation. The examples are shown in Table 5-1.

Verbal monitoring means participants using verbal communication to coordinate their ongoing or intentional behaviors [Hornecker, Marshall, Dalton, & Rogers, 2008]. My observation indicates that all the intra-group collaborations are conducted without

Table 5-1: Intra-group collaborations

Feature used	Type	Example
Personal territory	Divide ownership	A co-located team member dragged a card from near him to his co-located colleague's area when he found the colleague's name was on the card
Keyboard	Input information	Some participants create cards for their readability. When they want to edit the card, they intentionally rotate cards and move them to the person who holds the keyboard. And the keyboard holder will type the card for the card owner.
Concurrent touch	Improve group effectiveness	When the team decided to move story cards into an iteration, one participant drew an iteration and others put cards into it.
Concurrent touch and personal territory	Improve group effectiveness	When starting sorting cards, participants shrink the story cards near him/her. His/her colleagues saw his action and started shrinking the cards near them.
Concurrent touch	Facilitate co-located teammates	When a participant was dragging a card into an iteration, but the iteration has little empty space, another participant expanded the iteration for him.

verbal monitoring. Moreover, I did not find much interference within a co-located site. The questionnaire survey reports only one case that a participant "*was disturbed by co-located team members when using APDT*". The participant was in 3-person, DViT table-based team. He commented that only two concurrent touches were allowed on his table so that occasionally his touch was ignored by the system. Co-located collaboration might rarely be interfering with remote participants. I have observed once a scenario that a co-located sub-team deleted a story card, but the deletion was not noticed by his remote teammate, so that the remote participant asked "*does anybody find [the name of a story card]? It should be here*".

5.3.5 Inter-group Collaborations

Inter-group collaborations (collaborations between participants sitting in different rooms) increase the team's productivity. Table 5-2(a) shows two types of inter-group collaboration that were observed. Although rarely, I found some issues with inter-group collaborations. They are shown in Table 5-2(b).

I found that the interferences in Table 5-2(b) were resolved by verbal monitoring. My observation indicates that all the successful inter-group collaborations in our evaluation were accompanied by verbal monitoring. Meanwhile, the failed collaboration often lacked verbal monitoring or it was ignored by remote colleagues. Verbal monitoring was used for three purposes:

1. Notification of incoming changes: a remote participant wants to create a story card and states this "*everybody agrees with the task? ok, I will create a card* ."

Table 5-2: Inter-group collaborations and interferences

	Type	**Example**
Collaboration (a)	Distributed parallel work for increasing group productivity	At the end of meeting, all the participants at both sites worked together to sort cards on the center of their table surface.
	Helping remote teammates	One participant editing a story card and his remote participant points out a typo.
Interferences (b)	Unexpected behavior	One participant tried to drag a story card into an iteration. However, his remote teammate failed to realize his purpose and start moving the iteration preventing the first participant from accomplishing his goal
	Conflicting behavior	Two remote participants tried to move the same story card.
	Invisible body gesture	A participant pointed at the card he was talking about. However, the participant does not touch the table surface. His attempt at highlighting the card only worked for his co-located teammates

2. Coordinating remote assistance: Having decided two tasks, a participant suggests "*How about you [remote group] make one card for printing and we make one card for transaction log?*"

3. Describing ongoing behavior: One participant said that "*I am trying to take them [story cards] out of the iteration and try to re-prioritize them*". Knowing her goal, remote participants started helping her to move cards.

Verbal monitoring is accepted by participants. In my evaluation, none of the participants complained to the verbal monitoring and they did not comment that they were hindered by their verbal monitoring.

5.4 Interpretation of Findings

In this section, I first discuss if using distributed tabletops for multi-group agile planning meetings is useful. I then talk about the impact of our DViT and FTIR tabletops on agile planning collaborations.

5.4.1 Distributed Tabletops Sufficiently Support Distributed Agile Planning

Distributed tabletops sufficiently support multi-group agile planning meetings. My observations and surveys support this statement from five aspects:

1. The tabletop and conference call setup provides a real-time, unambiguous exchange of verbal and nonverbal information. It guarantees that both teams can interact with the same shared information and that all team members have a consistent view of the current state of the planning process.

2. We observed different types of territories and orientations were used to facilitate the interactions of individual participants and the whole distributed group.

3. Multi-group participants are satisfied with the interaction approaches provided by our distributed agile planning application. The observations and questionnaire results

reveal that participants positively acknowledge the convenience and flexibility of using finger touch, gestures and keyboard input.

4. Intra-group collaborations were often observed. The tool uses features of tabletops (personal territory, re-orientations, and parallel work) to facilitate both individual collaborators and the co-located sub-group. The inter-group collaborations rarely interfere within co-located subgroups. Even to remote collaborators negative interference not often observed and always quickly resolved by verbal communication.

5. Inter-group collaboration is found to assist agile planning across distributed sites. The table-based interface played a positive part to support distributed parallel work, interact with remote teammates and increase the group productivity.

5.4.2 Remarks on Current Tabletop Technologies

I found some issues that negatively affected the experience of using tabletops for distributed agile planning meetings. I realize that most issues are caused by the hardware limitations of our tabletops. Although the limitations do not block the completion of agile planning tasks, I think it is still valuable to report the problems for supporting the future design of similar tabletop applications.

Some participants reported that gesture strokes are often not recognized on our FTIR tabletop. I observed participants' behavior and realized that some participants' finger press is very soft so that the FTIR device does not recognize it as an incoming touch point.

The "fat finger effect" is another negative impact on tabletop-based interactions. It can be solved by increasing the size of UI widgets. However, due to the physical limitations of a display, the amount of user accessible information on the screen will be impacted if widget sizes need to be increased: As more pixels are needed to display and interact with the same amount of information, tables appear to be smaller than applications that are controlled by mouse interactions.

Both of our tabletops do not show the virtual seating arrangement. The use of personal space is only observed within co-located teams. Inter-group collaborations are limited to support the behaviors that are irrelevant to personal territory. However, the lack of a distributed personal territory does not impact the final outcome of agile planning meetings. Participants considered story cards as team assets and the use of personal space was very limited. Cards are sorted and saved in group territory.

Our setup did not convey body gestures between the two teams. This caused *unexpected behaviors*, *conflicting behaviors* and *invisible body gestures* issues. In the end, any resulting problems were quickly resolved by verbal communication.

To summarize: While current commercial or near-commercial tabletops do fall short of the state of research, they are – at least for our collaborative problem – an improvement over PC projectors (or no computer support at all). Their technical limitations did not have a big impact on the overall outcome of the application task as the table interactions played only a limited role in the overall work process.

5.5 Limitations

This thesis provides a concrete study of digital tables in the context of multi-site agile planning meetings. However, it is not yet clear how far the findings and conclusion can be generalized for other application domains. Due to the limitation of our lab settings, only FTIR and DViT tabletops are examined in this study. Moreover, as tabletops are not yet available in industrial software development teams, I had to use student groups to simulate industrial teams. The evaluation results have shown that APDT provides a synchronous workspace to communication distributed teams. However, the synchronization is tested based on local network of the University of Calgary. The performance of APDT needs to be tested in the World Wide Web, for example, in the context of supporting over-continent agile planning meetings.

5.6 Summary

The distribution of agile software teams increases the complexities of conducting agile planning meetings. Most agile planning tools are based on personal computers. In this context, tabletop might be more beneficial to support distributed, multi-sites collaboration. Now, with the development of surface computing, I use FTIR and DViT tabletops to support distributed agile planning meetings.

In my experiment, I observed the use of territory and orientation, user selection of interaction approaches, as well as inter- and intra-group collaborations. The results reveal that territory and reorientation facilitates remote/co-located teammates and distributed groups. Study participants were satisfied by the interactions provided by our distributed planning tool. Table interactions are often combined with verbal communications to facilitate the collaboration among remote participants and multi-groups. Limitations of the available hardware were overcome by verbal communication and the study participants considered the planning process to be successful.

CHAPTER 6: CONCLUSION

The agile methodology is widely applied in the software industry. Many companies, project teams, and research institutions have utilized agile methods to organize their software development. In order to fulfill their need for conducting agile project planning, a variety of project planning tools are available. However, some tools are unable to provide sufficient functionality to support all of the practices required by real-world agile teams, while others have usability issues that limit the user experiences. By observing the physical table-based agile planning meetings and the use of agile planning tools, I was motivated to combine both of them and find an applicable device to

1. Simulate the planning behavior on horizontal tables to support group collaborations and
2. Use the Internet and computers to automatically manage agile planning data and setting up a distributed agile planning workspace.

In this thesis, I utilized a digital tabletop, a computer-driven device that possesses a horizontal, tangible and multi-touch surface. I developed a tabletop-based agile planning tool – APDT – which uses the horizontal, multi-touch and large display of digital tabletops to create a collaborative planning environment for agile project planning. In addition, co-located and distributed evaluations are conducted to show the benefits and drawbacks of using digital tabletops for agile planning meetings. This chapter will summarize my research results in this study. I hope the experience will help future developers of agile project planning applications. The thesis contribution and future work is also presented.

6.1 Research Results

Although tabletops have been developed for several years, few attempts are made at using them to support project planning meetings. In this thesis, I developed a tabletop based agile planning tool and evaluate them based on co-located and distributed environment. During the development and evaluations, I gained a lot of experience and learned some lessons.

1. Choosing an appropriate tabletop: Digital tabletops are not yet widely available commercially. Different platforms vary in price, size, functions and interaction mechanism. While considering a tabletop application, it is necessary to investigate how often users will use the table, why they want to use it and what they will do on the table. The supported tasks might require different level of hardware capabilities, such as, users might need whole hand gesture, or the system needs to support user identification. Table size is another important factor that will be decided by size of target user groups.

2. Knowing Tabletop SDKs: The Tabletop SDKs provide controls that will facilitate development. The controls often employ internal tabletop functions, such as automatic implementation of two finger resizing. Using the "right" set of controls for a new application will significantly reduce the amount of source code required to implement the needed functionality – reducing development effort and time to market. However, as a trade-off, the more hardware-specific tabletop controls are adopted, the harder it is to migrate the application to other types of tables.

3. Cautiously Organize the Interaction Approach: A tabletop provides several advanced interaction approaches, such as multi-touch, finger gesture, hand shape recognitions, handwriting recognition. Some attempts were even made to combine the hand operation with verbal commands [Tse, Shen, Greenberg, & Fortlines, 2006]. The use of the various interaction approaches must be based on the context in which the tabletop application will be deployed. For example, the target users might feel it “funny” to talk to the computer, particularly in a group activity. For application development, using real customers to evaluate the interaction approaches is beneficial.

4. Remove “Coolness” Effects: Although being developed for many years, tabletop technology is still novel to most users participating in usability studies of tabletop applications. In my evaluation, some participants felt excited when playing with the tabletop. As a result, their comments to the tabletop and APDT might be biased by their feeling of “cool” and “fun”. Using a large number of participants that cover several age levels might be applicable to overcome the biased effect. The effect will also likely be reduced when digital tabletops become more commonplace.

6.2 Thesis Contributions

This thesis contributes to the research of digital tabletop interactions and agile methodologies. It provides a new tool to facilitate co-located and distributed team collaborations. Moreover, it extended the use of digital tabletops, enriched the type of tabletop applications and help studying the interactions with distributed tabletops.

Tool Development: In this thesis, a tabletop-based agile planning tool, APDT was introduced. The thesis includes its design goals, functionality, interactions and facilities for distributed communications. APDT explores using digital tabletops, an emerging HCI technology to support group collaborations. By employing the interactive feature of tabletops, APDT allows for more intuitive interactions among the individuals, groups and planning artifacts than other tools.

Tool Analysis: Chapter two reviews the development of agile planning tools and tabletop technologies. I used Liu's criteria to compare the existing, typical planning tools and showed its advantages and shortcomings. The comparison provides an overview to the state-of-the-art of the tools for agile planning meeting. It also indicates that, compared to personal computers and physical tables, tabletops provide more functions and user interactions to support distributed agile planning meetings.

Tool Evaluation: I organized evaluation sessions to study using digital tabletops to support co-located and distributed agile planning meetings. This thesis presented evaluation goals, methodology, participants and evaluation contexts. Also, evaluation results are carefully analyzed and listed in Chapters 4 and 5. The results exposed usability issues of APDT and listed user comments and suggestions which help understanding the collaborations of participants when using APDT in agile planning meetings. It also investigates the personal spaces, reorientation, intra- and inter-group collaborations within distributed agile planning meetings. This is an attempt at using the agile planning context to explore the interaction features of distributed tabletops. Also, it shows that our tabletops sufficiently support distributed agile planning meetings, although some minor problems such as the handwriting recognition exists.

6.3 Future Work

APDT has shown promise in its ability to improve support for agile planning meetings. However, there is always room for improving the tool and augmenting research. Since some limitations of APDT and the evaluation process have been pointed out in Chapter 4, and 5, the future plan is to solve the problems and enhance the validity of the evaluation.

6.2.1 Integrating the Changes of the Tabletop Technology

There are two major problems that hinder the use of APDT for practical agile teams. APDT is now designed for particular hardware (DViT and FTIR) (see Chapter 3.4). Moving it to a new tabletop device (such as Microsoft surface) requires rewriting part of the APDT source code to hook it up with the new hardware. With the boom of commercial tabletops, this will become a bottleneck of using APDT on newly released commercial devices. A study of setting up a generalizable component for configuring tabletop application on different platforms has been started by my colleague. I believe using the results will be beneficial for the deployment of APDT.

Tabletop technology is rapidly developing. Although present off-the-shelf tables have some functional limitation, such as being unable to identify a user, and invisible remote body gestures, they will be improved and be exposed to several new features created by tabletop researchers. The future work for me is to keep pace with the development of tabletop technologies and keep integrating new features of tabletops to APDT so that agile developers will be supported even better.

6.2.2 Conducting Field Studies

Even though my evaluations of co-located and distributed participants provides valuable insight to guide the development of tabletop agile planning tools, as well as gauging the feasibility of using tabletops, the participants consisted of university students. Most of them understand the basic concept of agile development, but lack the practical experience of conducting agile development for industrial projects. To provide more generalizable results, field studies which involve agile teams from the industry should be organized. These would also allow a more reliable answer to the question if digital tabletops make an actual difference for distributed agile planning.

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APPENDIX A: ETHICS APPROVAL

UNIVERSITY OF CALGARY

CERTIFICATION OF INSTITUTIONAL ETHICS REVIEW

This is to certify that the Conjoint Faculties Research Ethics Board at the University of Calgary has examined the following research proposal and found the proposed research involving human subjects to be in accordance with University of Calgary Guidelines and the Tri-Council Policy Statement on *"Ethical Conduct in Research Using Human Subjects"*. This form and accompanying letter constitute the Certification of Institutional Ethics Review.

File no:	**5048**
Applicant(s):	**Frank Maurer** Yaser Ghanam* Xin Wang *
Department:	**Computer Science**
Project Title:	**Examination of the Impact of Software Tools to Support Distributed Agile Project Planning**
Sponsor (if applicable):	

Restrictions:

This Certification is subject to the following conditions:

1. Approval is granted only for the project and purposes described in the application.
2. Any modifications to the authorized protocol must be submitted to the Chair, Conjoint Faculties Research Ethics Board for approval.
3. A progress report must be submitted 12 months from the date of this Certification, and should provide the expected completion date for the project.
4. Written notification must be sent to the Board when the project is complete or terminated.

Nov. 6/07

J. Kent Donlevy, Ph.D, LLB,
Acting Chair
Conjoint Faculties Research Ethics Board

Revised Date:
December 12^{th} 2006
Original Date:

Distribution: (1) Applicant, (2) Supervisor (if applicable), (3) Chair, Department/Faculty Research Ethics Committee, (4) Sponsor, (5) Conjoint Faculties Research Ethics Board (6) Research Services.

2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4 • www.ucalgary.ca

UNIVERSITY OF CALGARY

CONJOINT FACULTIES RESEARCH ETHICS BOARD

Annual Renewal / Progress / Final Report

Research Services, ERRB Building, Research Park

Submit by email to: rburrows@ucalgary.ca

1. Applicant: (USE RESTRICTED: Faculty, students, staff from the UofC)

Name

Frank Maurer , Xin Wang, Yaser Ghanam

Department/Faculty Department of Computer Science, Faculty of Science

E-mail Address maurer@cpsc.ucalgary.ca	Telephone: 403-220-3531

If you are a student, include your supervisor's name and email address here

2. Other Participants: If another person is involved in the project, please provide their name, department or other details as required to identify them. Use an attachment, if necessary

3. Project Details:

3.1 Exact Title of the Project (and File No. if available)

Examination of the Impact of Software Tools to Support Distributed Agile Project Planning FileNo. 5048

3.2 Have you commenced this research? [X] Yes When did it commence? Date: December 12th 2006

[ ] No If no, why not (attach)

3.3 Is the study completely closed to all research activity? [ ] Yes When was it closed? Date: ________

If the study is not completely closed, what is the expected date? Date: November 18th 2009

3.4 How many people participated in the research? 10

3.5Have all modifications been reported? [X] Yes [ ] No (If no, please attach)

3.6 Have the results been published or presented? [ ] No [X] Yes, if yes, indicate where results can be located.

Xin Wang, Frank Maurer: Tabletop AgilePlanner: A Tabletop-Based Project Planning Tool for Agile Software Development Teams. the 3rd IEEE Tabletop and Interactive Surfaces 2008, TABLETOP 08, Amsterdam, Holland, Oct 1st-4th.

Xin Wang, Yaser Ghanam and Frank Maurer: From Desktop to Tabletop: Migrating the User Interface of Agile Planner. Engineering Interactive Systems 2008 - The 2nd Conference on Human Centered Software Engineering (EIS/HCSE2008), Italy.

Robert Morgan, Frank Maurer: An Observational Study of a Distributed Card Based Planning Environment, Proceedings 9th International Conference on Agile Processes and eXtreme Programming in Software Engineering (XP2008), Limerick, Ireland, Springer, 10-14 June 2008.

Robert Morgan, Jagoda Walny, Henning Kolenda, Estaban Ginez and Frank Maurer: Using Horizontal Displays for Distributed & Collocated Agile Planning, Proceedings of the 8th International Conference on Agile Processes in Software Engineering and eXtreme Programming (XP 2007), Como, Italy 2007 (Springer).

Yaser Ghanam, Xin Wang and Frank Maurer: Utilizing Digital Tabletops in Collocated Agile Planning Meetings. Agile Conference 2008, Toronto.

Sebastian Weber, Yaser Ghanam, Xin Wang, and Frank Maurer: APDT: An Agile Planning Tool for Digital Tabletops, Proceedings 9th International Conference on Agile Processes and eXtreme Programming in Software Engineering (XP2008), Limerick, Ireland, Springer, 10-14 June 2008.

3.7 Have there been any complaints about the research [X] No [ ] Yes, if yes, please attach information with details.

Signature of Applicant:

Thank you for submitting your **report** on the above protocol.

As Chair of the Conjoint Faculties Research Ethics Board, I am pleased to advise you that ethical approval for this proposal has been extended to: NOV 30 2009. Please note that this approval is contingent upon strict adherence to the original protocol. Prior permission must be obtained from the Board for any contemplated modification(s) to the original protocol. An annual progress/final report concerning this study will be required by NOV 30 2009

Please accept the Board's best wishes for continued success in your research.

Janice P. Dickin, Ph.D., LLB, Faculty of Communication and Culture and
Chair, Conjoint Faculties Research Ethics Board

Date: NOV 18 2008

UNIVERSITY OF CALGARY

MEMO

Conjoint Faculties Research Ethics Board (CFREB)
Research Services Office
Main Floor, Energy Resources Research Building
Research Park
Telephone: (403) 220-3782 or (403) 210-9863
Fax: (403) 289-0693
Email: csjahrau@ucalgary.ca or rburrows@ucalgary.ca

To: Dr. Frank Maurer and Mr. Xin Wang
Department of Computer Science

Date: December 16, 2008

From: Dr. Janice P. Dickin, Chair
Conjoint Faculties Research Ethics Board

Re: Approval of Modification for: Examination of the Impact of Software Tools to Support Distributed Agile Project Planning
Original Approval Date: 2006/12/13
File No: 5048

The Certificate of Institutional Ethics Review issued on December 13, 2006 continues in force and extends to the modifications as set out in your email/memo dated December 16, 2008. Your request to recruit student participants from a course for which you are the Teaching Assistant and use a revised recruitment script to this effect, is approved, as described.

You should attach a copy of the documentation you provided in order to request the modification, together with a copy of this memorandum, to the original Certification in your files.

Sincerely,

Janice Dickin, Ph.D., LLB., Professor
Faculty of Communication and Culture
Chair, Conjoint Faculties Research Ethics Board

Cc:

APPENDIX B: PRE-QUESTIONNAIR FOR CO-LOCATED EVLUATION

Agile Background:

1. For how many years, you have been working on the software development/computer related research?

2. Do you know "agile development"?

______Know Nothing

______Know some concepts

______Has some real experience (course project or real project)

3. Do you have any **working** experience on agile development?

______No

______Yes, course project

______Yes, business project

Tabletop Background:

1. Have you ever used tabletop?

______Never Used ______ One or Two times ______ Occasionally_____Often Used

2. Have you ever used touch sensitive device? For example, tablet PC, SMART Board?

______Never Used ______ One or Two times ______ Occasionally_____Often Used

Please specify: (the name of device)

APPENDIX C: TASK SCRIPT FOR INDIVIDUAL EVALUATION

1. Create a story card with your finger touch

2. Enlarge the card (Look at instructions below – No. 1)

3. Change the color of the card to red (Look at instructions below – No. 2)

4. Use the keyboard to input "test" as the card title

5. Change the card status at the bottom left of the card from "Defined" to "In Progress"

6. Delete the story card

7. Use "undo" to get the card back.

8. Pass the card to the tester opposite to you (Look at instructions below – No.3)

9. Put the card on the top left corner of the table and reorient it properly so that it is readable for the tester opposite to you

10. Use the microphone to create iteration

11. Move the iteration to the bottom right of the table.

12. Use the microphone to create a new story card

13. Use your finger tip to write (Look at instructions below – No.4)

14. Move the card into the iteration

15. Delete any story cards and iterations on the table surface

<u>Instructions</u>

1. Drag the bottom right corner of the card to resize it

2. Select the card and then use the palette to change the color

3. The card can be tossed on the surface of screen

4. Double click the card to make it handwriting enabled, write on it, and then double click again to exit writing mode

APPENDIX D: POST-QUESTIONNAIRE FOR CO-LOCATED EVALUATION

Please rank the following tasks on a scale from 1 to 5:

1. Obtaining **help**

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

2. **Creating** a story card

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

3. Changing the **color** of the story card

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

4. **Deleting** a story card

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

5. **Rotating** a story card

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

6. **Resize** a story card

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

7. **Moving** a story card

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

8. **Tossing** a story card

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

9. **Handwriting** on a story card

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

10. Using **keyboard** to write on a story card

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

11. **Creating** iteration

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

12. **Deleting** iteration

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

13. Using **undo** functionality

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

14. Using **voice** commands

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

15. Which method did you prefer to create a story card/iteration?

_____Gesture ____Speech

16. Which method did you prefer to write on the story card?

_____Keyboard ____Handwriting

17. Did you use the mouse at all when interacting with the application?

____Yes ____No

If Yes, to do what?

18. What did you like the most about this application?

19. What did you dislike the most about this application?

20. What one thing you would like this application to have?

APPENDIX E: QUESTIONNAIR FOR DISTRIBUTED EVALUATION

1. I am using

   ____SMART Board ____SMART Table

2. Setting up your virtual seat before an agile planning meeting is

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

3. I would prefer to use

   ____Finger touch ____Mouse

4. Using finger touch is

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

5. The best used gesture is (if any):

6. Using gesture is

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

7. Remembering gesture definition is

   Very Difficult Very Easy

   ____1 ____2 ____3 ____4 ____5

   Comments:

8. **I have ever misusing gestures**

____Never happened ____Occasionally ____Sometimes ____Always happened
Comments:

9. I feel **Ok** without watching gestures drawn by remote participants (Yes/No)
Comments:

10. I feel using **keyboard** to fill story card is

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

11. I feel using **handwriting** to fill story card is

Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5

Comments:

12. I will prefer using handwriting/keyboard because

13. I was disturbed by **co-located** team members when using APDT

____Never happened ____Occasionally ____Sometimes ____Always happened
Comments:

14. I was disturbed by **distributed** team members when using APDT

____Never happened ____Occasionally ____Sometimes ____Always happened
Comments:

15. Telepointer provided **enough** information to understand remote participants' interactions (Yes/No)
If No, what do you think is missing?

16. Realizing what remote participants were doing is
Very Difficult Very Easy

____1 ____2 ____3 ____4 ____5
Comments:

17. The screen of my table is

____ Too large ____Appropriate ____Too small

18. The size of UI artifacts is

____ Too large ____Appropriate ____Too small

19. I feel audio conference is

____ Enought ____Not enough, I want video conference
____Not enough, I want:

APPENDIX F: CO-AUTHOR PERMISSION

UNIVERSITY OF
CALGARY

August 11, 2009

University of Calgary
2500 University Drive NW
Calgary, Albert
T2N 1N4

I, Frank Maurer, give Xin Wang permission to use co-authored work from our paper "Utilizing Digital Tabletops in Collocated Agile Planning Meetings" and "Tabletop AgilePlanner: A Tabletop-Based Project Planning Tool for Agile Software Development Teams" for Chapter 3 and 4 of his thesis and to have this work microfilmed.

Sincerely,

Frank Maurer

UNIVERSITY OF
CALGARY

August 11, 2009

University of Calgary
2500 University Drive NW
Calgary, Albert
T2N 1N4

I, Yaser Ghanam, give Xin Wang permission to use co-authored work from our papers "Utilizing Digital Tabletops in Collocated Agile Planning Meetings" for Chapter 4 of his thesis and to have this work microfilmed.

Sincerely,

Yaser Ghanam