Idea generation support system utilizing digital pen and paper

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Abstract

We propose an idea generation support system utilizing digital pen and paper technology to help individual user collect, manage, and keep track of idea generation progress as well as help improve reusability of past handwritten data. The proposed system consists of two main features. First is the data collection tool which used for storing past generated ideas and alternatives in handwritten form. Second is the idea progress visualization tool for visualizing writing activity occurs during idea generation process in a structured way. The idea progress visualization tool provides interface for reviewing past generated ideas and alternatives, and reusing those data to help user explore new options and refine ideas.

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Chapter 1   Introduction

1.1   Role of pen and paper in idea generation process

According to J. Foster [1], idea is a result of mental activities where previous knowledge, information, facts, or ideas were recombining in a way of forming a new concept. The idea generation process involves non-intentional ideas rather than the intentional one and that is a long-term process, which idea slowly evolved and matured over time [2]. With the rapid technological advancement, there are many tools available nowadays to help record and manage those idea generated in our daily life. However, they have focused rather on the short-term temporal thinking and relied heavily on computer-based input devices [3, 4]. These available tools require time and training effort for users to get familiarized with and can sometimes cause distraction to users from their intended idea generation tasks. The research experiment on naturally occurring idea generation[6] has found that group using computerized support system generated fewer ideas compare to group using flipcharts or paper (due to much of the time was devoted to managing the system itself rather than spending on coming up with idea).

Due to these reasons, even today pen and paper are still considered one of the most easiest and comfortable tools used for express and communicate one's idea, thought and feeling. In idea generation process, pen and paper play an important role in knowledge creation and management due to their ease of navigation and mobility, to capture one's idea effortlessly in both forms of handwriting or sketching. According to the observation made by K. Misue and J. Tanaka [5], handwriting satisfies many requirements necessary to support creative activities since it offers a more natural and informal way to record data. For example, sketches and hand drawings with pen and paper can support idea generation by help extracting vague concept into a more concrete form [10]. Also, utilizing pen and paper for sketching can help encouraging feedback on idea since it signal work in progress and invite for further improvement and refining ideas [11].

Based on the above reasons, we can say that pen and paper can be considered as one of the most suitable tools to use in idea generation process. And thus, handwritten data generated during writing activity in the process could be very useful in help provide many benefits to idea generation process.

1.2 Problems of pen and paper usage in idea generation

1.2.1 Difficulty in tracking alternatives and changes occur during idea generation process with traditional notes paper

As state above, pen and paper usage can provide many benefits in idea generation process. However, there lies challenge in concerning how to effectively manage those handwritten data in idea generation process where alternatives and decisions occur repeatedly until user reaching final solutions. For example, as illustrated in Figure 1-1, handwritten data concerning topic of "Brainstorming tool" were written across multiple pages, which made it difficult to review and keep track of idea progress on this particular topic (idea about "Collaborative brainstorming tool using table top" was written on different page). Also, since unrelated topic (idea about "New Phone Design") was written on the same page as well, users might find it difficult to locate the data at first glance. Due to difficulty in tracking changes and monitoring ideas progress, pen and paper usage might hinder users from generating new alternatives or improving ideas over time.
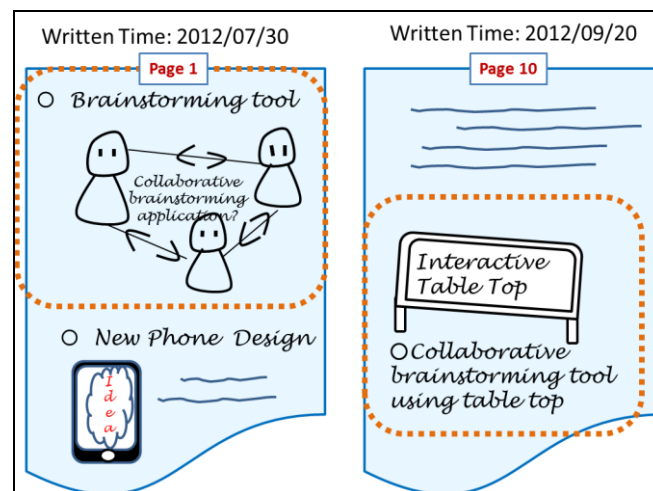
Figure 1-1: Difficulty in keeping track of handwritten ideas in traditional notes paper

1.2.2 Difficulty in reusing past handwritten data

Another problem of handwritten data is concerning its reusability. For example, users drew a sketch on paper as shown in order from Figure 1-2-1 through Figure 1-2-3. Afterward, if users want to create different version of this sketch such as shown in Figure 1-2-4, he/she needs to start drawing from scratch since handwritten data of Figure 1-2-1 has been already redrawn to Figure 1-2-3. Due to this, we find that handwritten data also posed problem due to its limited reusability which made it difficult for users to explore different options and alternative.
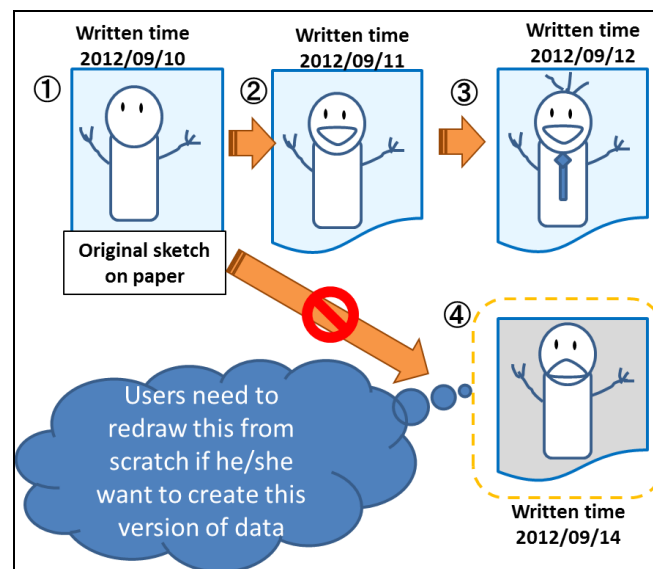
Figure 1-2: Difficulty in reusing past handwritten data

1.3 Research objective

Our research aims to solve the above problems by offering a more innovative way to collect, manage, keep track of handwritten data generated in idea generation process and improve its reusability for users to explore and refining ideas. Examples of generated handwritten data can ranges from sketching of image in conceptual design, handwriting memo on idea progress, diagrams and flowchart illustrating idea concept and etc.

To summarize, our research objectives we aim to achieve are as following.
1. Visualizing writing activity in idea generation process in a structured way which can help support users for later analysis of alternative choices, learn and

monitor about their past generated ideas, and ultimately can help improved them over time.

2. Improving reusability of past handwritten data which can help users developing and testing new ideas, exploring different alternatives and choices in idea generation process.

1.4   Research approach

Our research approach is to utilize digital pen and paper as idea capturing and processing tool to support users in idea generation process. Reasons for choosing digital pen and paper are first, they could offer both advantages of the computation capability while keeping affordance of physical copy of paper as well. Second, since they can also act similarly to traditional pen and paper, collecting and processing handwritten data impose little burden to users and do not invert their attention from the intended idea generation tasks.

We propose to provide innovative interface to manage and track idea generation progress by using data provided by digital pen and paper such as written time, stoke data position on page. Rather than process handwritten data with OCR and store them in text or image format, we choose to collect handwritten data in their raw form, which consisting of pen's stroke coordination on paper. These data will be used to help in grouping related idea together to improve reviewing and tracking idea progress. Also, the digitized handwritten data will be used to help in versioning handwritten data over time to make it become more reusable.

1.5   Preliminary Knowledge

1.5.1   Digital Pen

Digital pen is an input device that writes exactly the same way as an ordinary ballpoint pen. However, it has built-in camera, image microprocessor, communication devices such as Bluetooth to help store and convert handwritten information into a digital format. When writing with the digital pen, a built-in camera takes snapshots of pen strokes and registers the pen's movements in relation to its position on the page. The data contains position coordinates of written data, pressure and speed of writing, time of use, inclinations and rotations. Once the data stored in the built-in memory, it can be transferred to PC or other devices via Bluetooth or a USB docking station.

1.5.2 Digital Paper

Digital paper is a paper which its surface covers with the patent-protected dot pattern, developed and licensed by Anoto, a Swedish company. Any paper format can be printed with this pattern, which works in conjunction with a digital pen to digitize handwritten information. The pattern consists of numerous small black dots that can be read by a digital pen. Every pattern consists of a unique combination of dots encoded with the position information, to pinpoint the exact location of each pen stroke on the paper.

Chapter 2   Related work

This research draws from prior work in two areas: Pen-and-Paper User Interfaces and digital pen and paper technology in idea generation process. In this section, we explain how these works contributed to our system's design.

2.1   Pen-and-Paper User Interfaces

Since our work also focuses on visualizing writing activity occurs during idea generation process, we had performed surveys on field related to Pen-and-Paper User Interfaces (PPUIs) as well. As research on PPUIs concerns integration of paper-based and digital information [7], study on previous works were conducted to provide guideline in designing real paper interaction for structuring, organizing and visualizing ideas. For example, ButterflyNet [12] utilized digital pen and paper to facilitate collection and organization of different type of data (e.g. handwritten data, digital photographs and video clips). These data were associated with each other by timestamp and gesture based command perform on digital paper. Capture data can be reviewed through a browser together. Similar concept of automatic time-based correlation of content was used in our system, which utilizing written time to group stroke data content together.

Prior research on interface design for pen-based interaction by J. Steimle [13] and C. Liao et al. [14] inspired our early system design as well. Their researches provide guideline for designing pen-based linking and tagging of handwritten data.

2.2   Digital pen and paper technology in idea generation process

There have been a range of researches done in the area of utilizing digital pen and paper technology to support idea generation process. PaperSketch [15] introduced an interactive paper-digital tool used for supporting collaborative remote sketching. This research utilized digital pen for paper-based sketching. To help assist collaborative creative design between multiple users, it offered the GUI for display local and remote shared sketches drawn by other users on computer screen in real-time. However, due to focus on providing support on short-term activity, there is no function to support reviewing and tracking of past generated ideas. For example, this system offers no functionality for viewing whom and when those ideas were generated (since sketch data

were stored as image file). Thus, this limited reusability of sketch data since users can't select and save only portion of data generated by particular users or time.

Other researches combined digital pen and paper technology with other devices such as interactive tabletop and large displays. For example, Nice Discussion Room [16] and Idea Playground [17] integrated digital pen and paper with interactive whiteboard, laptop and mobile device to support creative process. Ideas inputted by digital pen and other devices are shown on interactive whiteboard. Digital pen are used to link and group digital content displayed on interactive whiteboard. Functions for copying, saving and restoring the whiteboard's state are also provided to help support long-term idea generation. While these researches similar to our proposed system in the way that past generated idea can be reused for refining idea over time, their system restricts idea generation process to be time and place specific only.

Research on utilizing digital pen and paper technology for supporting specific idea generation technique were conducted as well. For example, AffinityTable [18] combined digital pen and paper with an interactive table and tangible tool for support affinity diagraming during collaborative design process. Group KJ Method Support System [19] proposed by M. Miura also utilizes digital pen to digitize ideas written on a label during the GKJ session. Digital pen is used for capturing position and orientation of labels as well as their content. These digitized data were available for immediate sharing, which are shown as diagram. Although these researches similar to our system in trying to visualize idea progress, their focus on specific use in group activity and idea generation technique limited their capability to support for individual use in daily life.

IdeaVis [20] used digital pen together with large displays to support co-located sketching sessions. This system introduced concept of visualizing design activity, which sketches produced during the session by multiple users are displayed in a tree-like versioning history. When users perform sketching, a digital version will be stored in the system and displaying as tree in clockwise direction around a central node. The system will create new version and a link from the previous version when a different pen is used on the same paper. Utilizing this visualized tree, users can print and merge different sketches together. This research greatly resembles our research in a way that idea progress is visualized in tree structure, which past generated idea can be reused to help in explore alternative and refine ideas. However, since this system visualized design activity as hyperbolic tree structure, they can only support visualization of only one idea's topic at a time. On the other hand, our visualized tree structure can be used to support tracking progress of multiple ideas which can be tagged and grouped together. Our proposed versioning interface also differs as well since it doesn't require users to use different pen or reprint data. Versioning of handwritten data in our system can be done both automatically and manually by utilizing time information provided by digital pen. Thus our system approach offers better advantage since it provides less interruption to users

during their idea generating activity. Our proposed merging interfaces also different from this system as well. In IdeaVis, multiple sketches will be automatically scale down and rearrange to fit on a single page. Our system however, offers interface for users to edit selected data (such as change in position and size) prior to merge process.

Chapter 3　Idea generation support system utilizing digital pen and paper

3.1　System overview

The proposed system utilizes the digital pen and paper technology [7] for idea generation support system, which individual user can collect and manage handwritten ideas data. Figure 3‑1 depicts our conceptual design that is used to implement the system
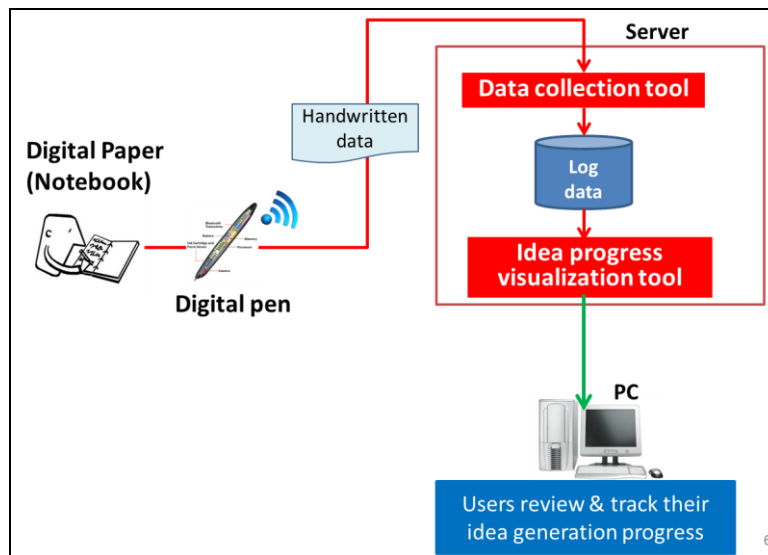
Figure 3-1: Conceptual design of idea generation support system

When users use digital pen to write ideas on the digital paper, the handwritten data is then captured and stored inside a built-in memory of that digital pen. The data can be transferred to the server either via a mobile phone using Bluetooth, or via PC using a USB port. Data collection tool is used to help convert and store handwritten data into the server as log data. The log data can be retrieved later through idea progress visualization tool, which users can review and track their idea generation progress via PC.

3.1.1　Data collection tool

Data collection tool is used for converting handwritten ideas into log data, and storing them in the centralized database. The handwritten data will not be converted into text

because we want to be able to store freeform handwriting such as drawing or sketch of ideas data.

Example of information that log data will contain are:

- Pen related data: Id of pen that used to recorded digital strokes
- Ink related data: stroke point data (x-y coordination, duration of ink stroke, start time when ink stroke was initiated, etc.
- Page address: Address of digital paper page

3.1.2　　Idea progress visualization tool

Idea progress visualization tool is used to retrieve log data and generate them as a virtual notebook for tracking idea's progress. We offer innovative method for retrieving and auto-compiling multiple ideas data written across notebooks and pages by utilizing digital pen and paper interface. Handwritten data written across multiple pages can be organized and re-compiled according to its relational strength to one another, by using the time when written or the content of those data.

To provide solution to first problem mention above, our first approach is to represent generated idea in tree structure which ideas of same topic can be grouped together and allow user to review generated idea according to their topic in order of the written time on digital paper. As illustrated in Figure 3-2, handwritten log data will be represented as branch of a tree, and can be viewed as a virtual note. Each branch represents a snapshot of handwritten data in particular time to help make it easier to tracking and review idea progress.
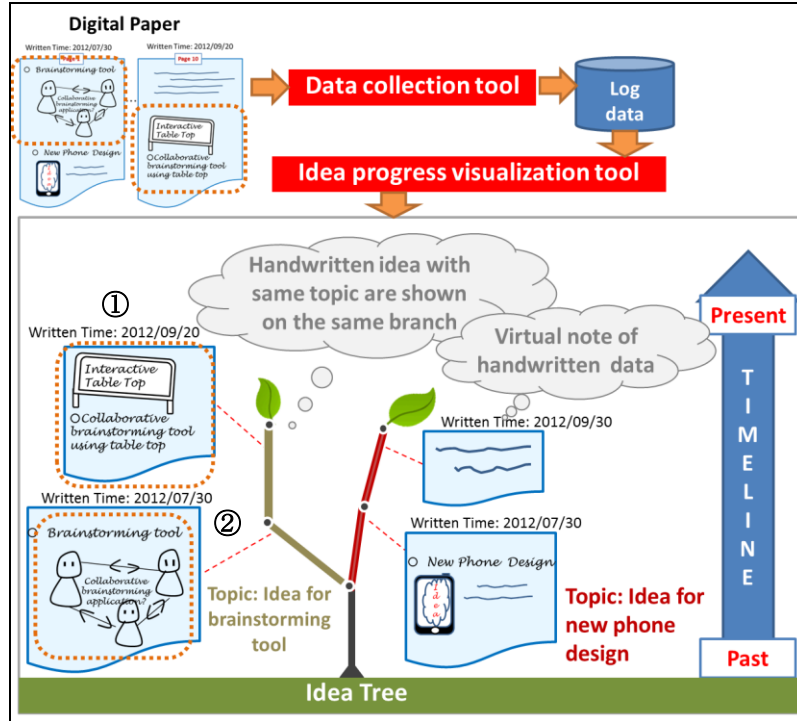
Figure 3-2: First approach of idea progress visualization tool

For example, users can use this tool to review and keep track of idea generation progress on the topic of "Brainstorming tool". As shown on Figure 3-2-1, the virtual note display on the first tree's branch of this topic will not display handwritten data of unrelated topic (idea for "New Phone Design") even though it was also written on the same page. On the next branch of this topic, only the log data of the same topic written afterward will be retrieved and shown as illustrated on Figure 3-2-2. The result could provide information such as how ideas change and evolve over time (for example, the "Brainstorming tool" was written on July 30th and was further improve as "Collaborative brainstorming tool using table top" on September 20th).

To provide solution to second problem mention above, our second approach is to provide interface that could allow users to print past version of handwritten data and reuse them as based-version to explore new alternative and refine ideas (Figure 3-3). We will utilize stroke data and written time information of handwritten data provided by the digital pen for versioning. Each version will be displayed as a snapshot of handwritten data in particular timeframe and shown as a virtual note on the tree structure.
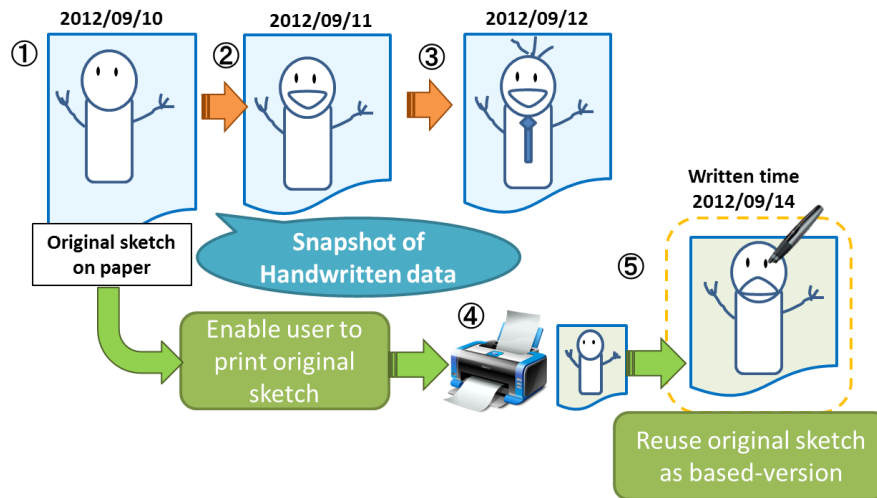
Figure 3-3: Second approach of idea progress visualization tool

3.2 System architecture

Table 1: System architecture of idea generation support system

System architecture
Digital Pen device ・ Anoto digital pen DP-201
Digital Pen SDK ・ Anoto-Maxell K.K 「Penit Navigator」
Software Framework ・ .NET Framework 4.0
Programming language ・ ASP.NET C#
Server ・ SQL Server 2008 R2
OS ・ Window 7

In our research, we have chosen Anoto digital pen DP-201 and the provided software development kit called Penit Navigator for collecting and transferring data written on digital paper from digital pen to PC. Due to requirement for pattern licensing and

printing of digital paper, we also utilize the SDK for creating form template to print on digital paper and for generating pattern data on digital paper.

As our software framework, we use .NET Framework for developing data collection tool and idea progress visualization tool. Both data collection and idea progress visualization tools were written in ASP.NET C# language. Our data collection tool was written as a .NET WinForm Application which utilizes the API provided by digital pen SDK to access to the temporary handwritten data stored on user's PC (these data will be deleted when transferring after being transferred to our server). Idea progress visualization tool is developed as an ASP.NET MVC application. The data collection tool is used for further processing handwritten data for our idea progress visualization tool and transferring them to save in the database of our server. This tool is built to be triggered automatically when data transferring from digital pen to PC is completed. Data in our system is stored on SQL Server 2008 R2 which runs above Window 7 OS.

Chapter 4　　System implementation

4.1　　Design form template for writing ideas

We utilize Anoto digital pen DP-201 and the provided software development kit called Penit Navigator. The SDK is used for managing pattern license for printing digital paper and for designing a form template that will be printed above the dot-pattern on digital paper. The functions which we used for our system can be summarized as followed

1. <u>Form Navigator</u>: Tool used for designing form template and printing digital paper.
   - To define entry fields' size and their coordinate
   - To define how handwritten data in each field will be processed (whether to process data as pen stroke data or image data or perform OCR and translates pen strokes into text.)
   - To define background image

2. <u>Form Register:</u> Tool for managing user-designed form.
   - To register and delete form template
   - To define application program which will be trigger after data transfer between digital pen and paper completed

3. <u>Form Processor and Data view</u>: Tools for processing handwritten data.
   - To process and temporary store handwritten data accessible via the API provided by SDK (The API is written in C# for the .Net Framework).
   With the provided SDK, we have designed a form template illustrated on Figure 4-1 to be used for developing our system prototype.

Figure 4-1: A form template of digital paper designed for developing system prototype

Utilizing the above functions, we have designed form template (Figure 4-1) of digital paper to be used in our system prototype. Our designed template consists of the following entry's fields.

1. Input field for writing idea title (Figure 4-1-1):
   - Handwritten data written on this field will be assigned and stored as the topic of idea

2. Input field for writing idea content (Figure 4-1-2)
   - Handwritten data written on this field will be assigned and stored as the content of idea and will be automatically grouped together as the same idea's topic written in input field as shown in Figure 4-1-1.

3. Command box for tagging and grouping idea content with the same idea's topic together (Figure 4-1-3):
   - While idea content of the same page can be automatically grouped together, users can also manually perform manual tagging and grouping of idea content as well. By checking on this command box before writing on the idea's content field, handwritten data across different pages can be grouped together as the same idea's topic.

4. Command box for storing snapshot of idea content at particular time (Figure 4-1-4):
   - This command box is used for manually segment handwritten data in idea's content field and allows those stroke data to be stored as group together.
   - By perform checking on this command box, handwritten data written prior to this will be defined as snapshot of grouped stroke data, which can be displayed and managed together.

5. Command box for transferring data to PC (Figure 4-1-5)
   - When use digital pen to check on this command box, digital pen will transfer all handwritten data to the PC. Upon successful transferring, the data stored on the memory inside the digital pen will be deleted.

4.2   Design database schema

As shown on Figure 4-2, currently our designed database consists of total 15 tables which used for storing handwritten data as log data.
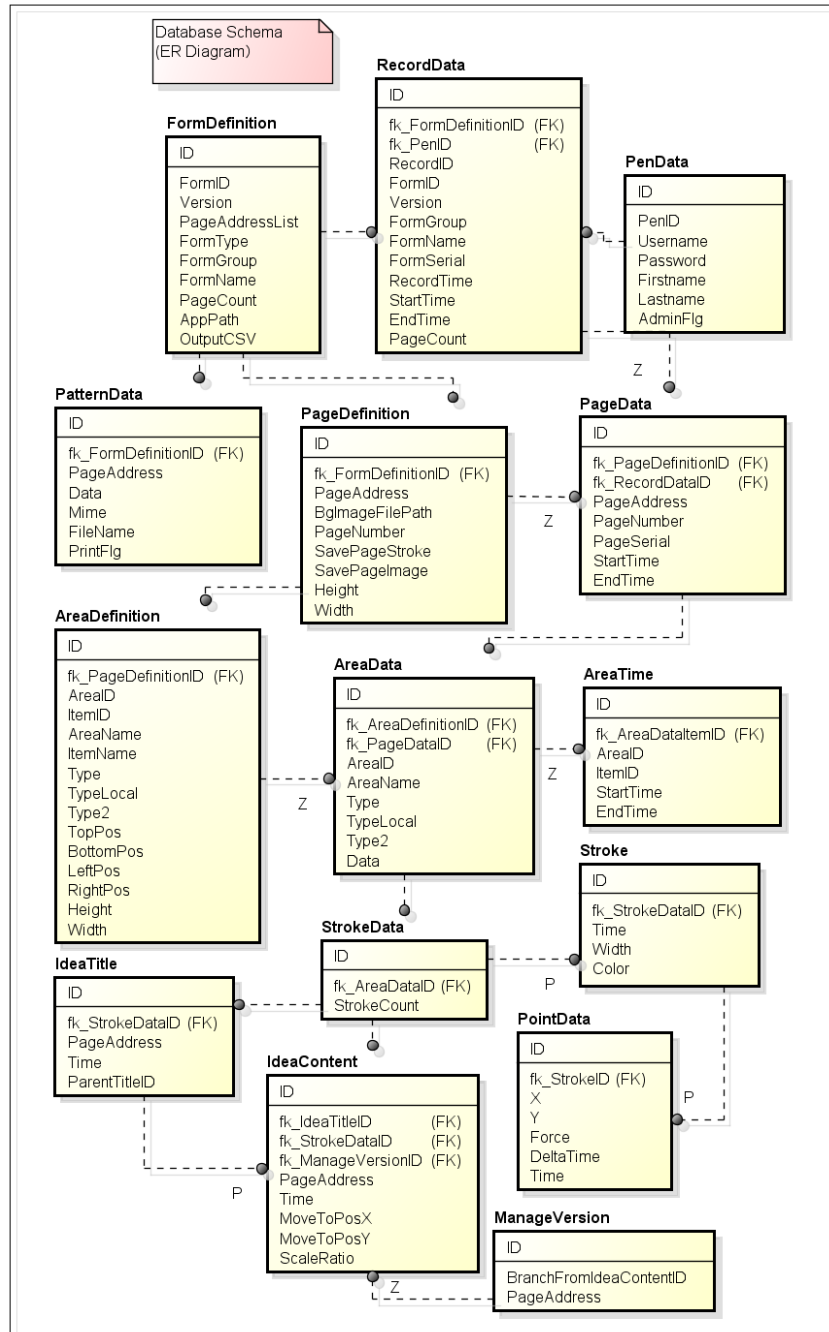
Figure 4-2: Entity Relation Diagram for idea generation supporting system

According to the roles and functions they perform, we can divide these tables into the following groups.

Table 2: Table's names and roles for idea generation support system

1. Table used for storing a pre-defined form template data	
Table's Name	FormDefinition Table, PageDefinition Table, AreaDefinition Table
Role	Store definition of form data such as name of the form, attributes of each form entry's field such as field's name, position, type of data to be stored (image data, stroke data or text data).
2. Table used for storing input handwritten data	
Table's Name	RecordData Table, PageData Table, AreaData Table, AreaTime Table, StrokeData Table, Stroke Table, PointData
Role	Store handwritten data input such as start time when ink stroke was initiated, x-coordinate and y-coordinate of each stroke, interval time between each coordinate
3. Table used for indexing and categorizing idea title and content of handwritten data	
Table's Name	IdeaTitle Table, IdeaContent Table, ManageVersion Table
Role	Store an index data of idea content and title which point to StrokeData table, versioning information of reused handwritten data such as index of parent data in idea content table or title table
4. Table used for storing digital paper's pattern data	
Table's Name	PatternData Table
Role	Store information related to digital paper's pattern data such as generated pattern file with form template in binary format, flag data for managing printing pattern
4. Table used for storing user information	
Table's Name	PenData Table
Role	Store user information such as Pen's ID, user's name and password used for login to our system

4.3   Design pattern data management system

In our research, we had developed Anoto pattern data management system which can export and store designed form template printed with dot-pattern data to our server. The reason for choosing to develop our own pattern data management system is first, due to limited functionality for managing past printed pattern data of the SDK pattern license management system. As shown in Figure 4-3, when users choose to print digital paper via SDK, the next available unique pattern data will be automatically generated at the

print time. Each pattern is assigned with unique pattern ID (ex. 21.49.9.0) which could be retrieved along with handwritten data and used to identify which page the handwriting was written.
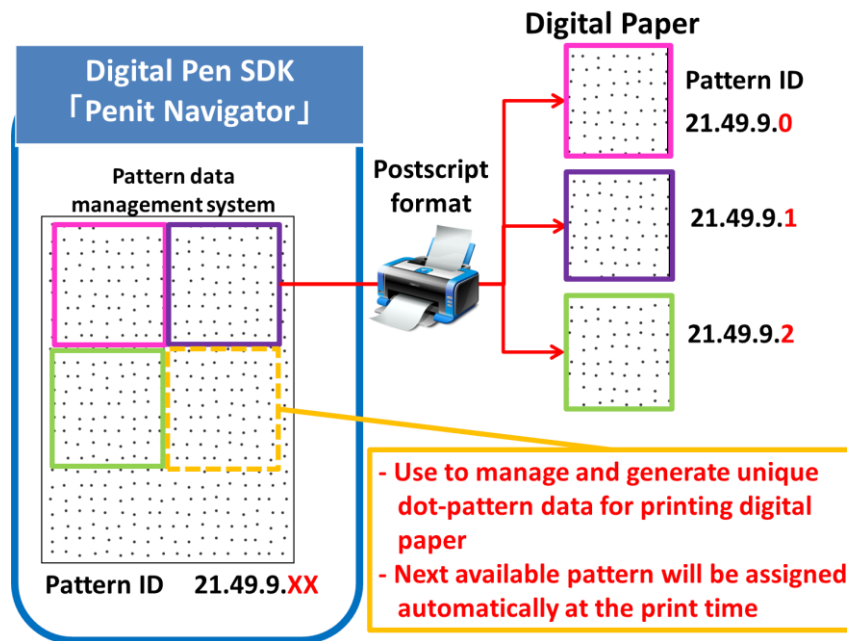

Figure 4-3: Digital pen SDK's pattern data management system

However, as shown in Figure 4-4 the SDK doesn't provide the functionality for reprinting past generated pattern data with handwriting. Thus, make it not possible for users to printing past version of handwritten data and reuse them as based-version for explore new alternative and refine ideas.
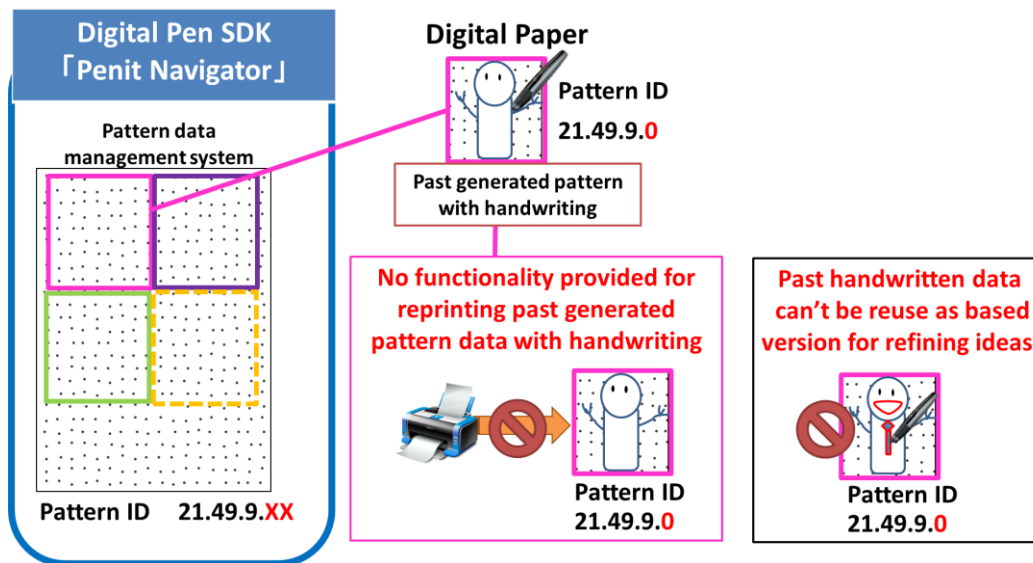
Figure 4-4: No functionality for reprinting past generated pattern data with handwriting

The second reason is due to the requirement of SDK's software license which only allow access to print function via the provided SDK only. This means users need to install the provided software in order to print and view data which resulted in limited accessibility of pattern and handwritten data to users.

Due to the above reason, we decided to develop our own pattern data management system which offer functions for managing pattern data, storing past generated pattern in database and allows access of those generated data via web. The implementation of our pattern data management system is shown in Figure 4-5.
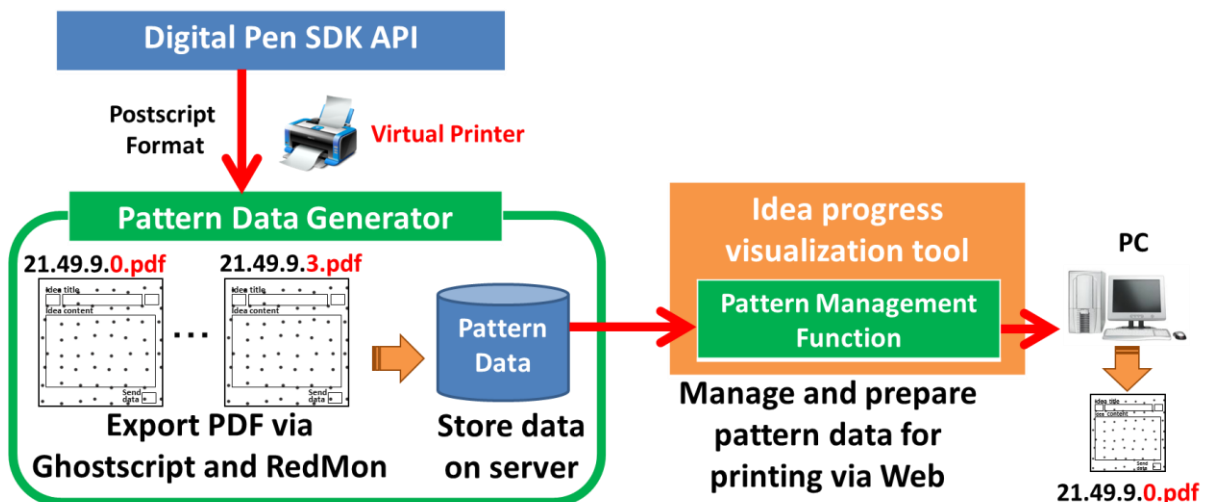

Figure 4-5: Flow for generating and storing digital paper pattern data on server

The system consists of Pattern Data Generator Program and Pattern Management Function, which are used for generating and storing digital paper pattern data on server, allowing users to select and print the digital paper via web. The Pattern Data Generator Program utilizes print's API provided by the SDK to send pattern data to virtual printer which is configured to export data in PDF format using Ghostscript and Redmon. Redmon was used as a print monitor to redirect generated pattern data in Postscript format to be handled and convert to PDF format through Ghostscript. We used Ghostscript's PDF writer as output device for exporting PDF file, which consists of dot-pattern data with our designed form template printed above.

As shown in Figure 4-6, first users are required to choose the prepared virtual printer and the form template associated with dot-pattern data used for printing digital paper. After finishing selecting, the program will display information related to pattern data such as form template's name, available print number in total (256 pages), number of already generated pattern data (0 page) and available number of pattern data left for printing (256 pages). Users can choose the number of copies in the combo box below before click the Generate button to perform PDF exporting and storing pattern data on server.
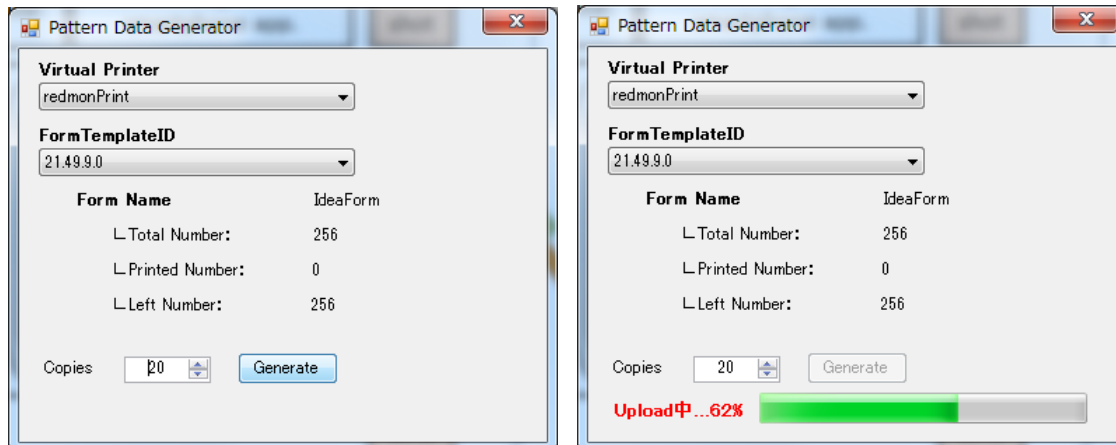

Figure 4-6: Screenshot of Pattern Data Generator program

After users have finished performed the above procedure, stored pattern data as shown in Figure 4-7 can be accessed through web via Pattern management function, which allows users to select and print digital paper (Figure 4-8, Figure 4-9). The generated pattern data are stored in binary format along with other information such as pattern ID (pattern ID is stored in table as page address in our database) and flag data for managing printed pattern (PrintFlg equals to 1 for already printed data).

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Figure 4-7: Generated pattern data are stored in database on server

As one of the application page of idea generation visualization tool, users can access to the Pattern management function by clicking Home Button at the top right area as shown in Figure 4-8. Users can choose number of copies to print via the combo box, which the maximum number of pattern data available to be printed is equal to the left pattern number store in database (in this case, users can only select up to 20 copies since there is only 20 pages of pattern data generated from previous procedure). When users click Print button, the Pattern management function will update flag data (update PrintFlg from 0 to 1) and display download links to the generated pattern file prepared by the Pattern management function.
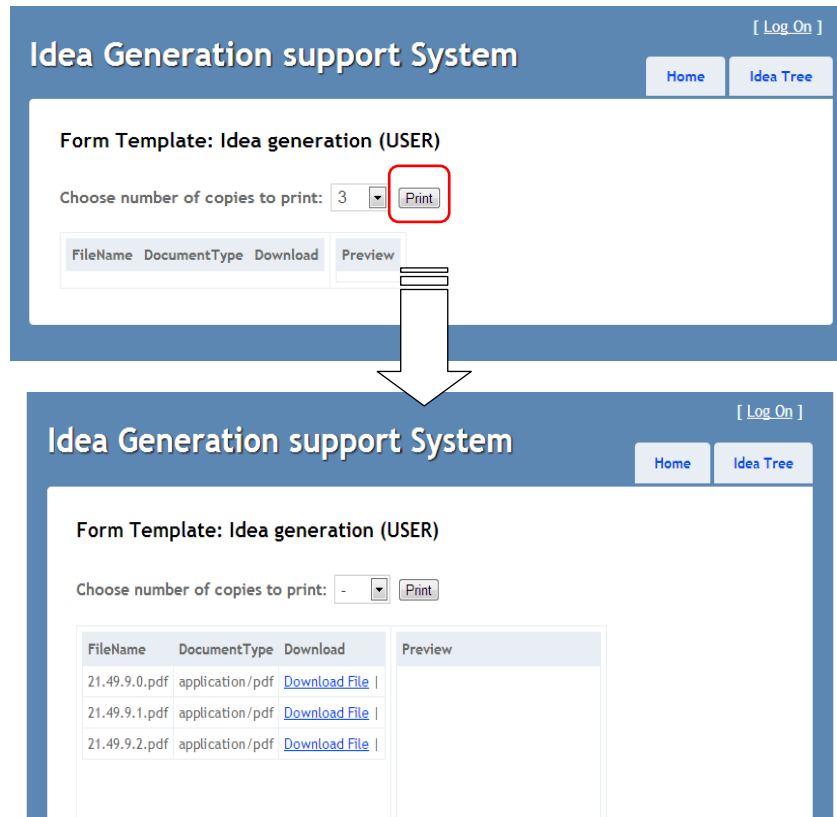
Figure 4-8: Application page of Pattern management function (USER's view)

In the current implemention, the Pattern management function display data differently according to the preset user's priviledge in our system. Users with administrator priviledge can access to ADMIN version of Pattern management function, which shown all stored pattern data in database (Figure 4-9). Pattern data that currenly being used will display "USED" in the Manage Pattern column.
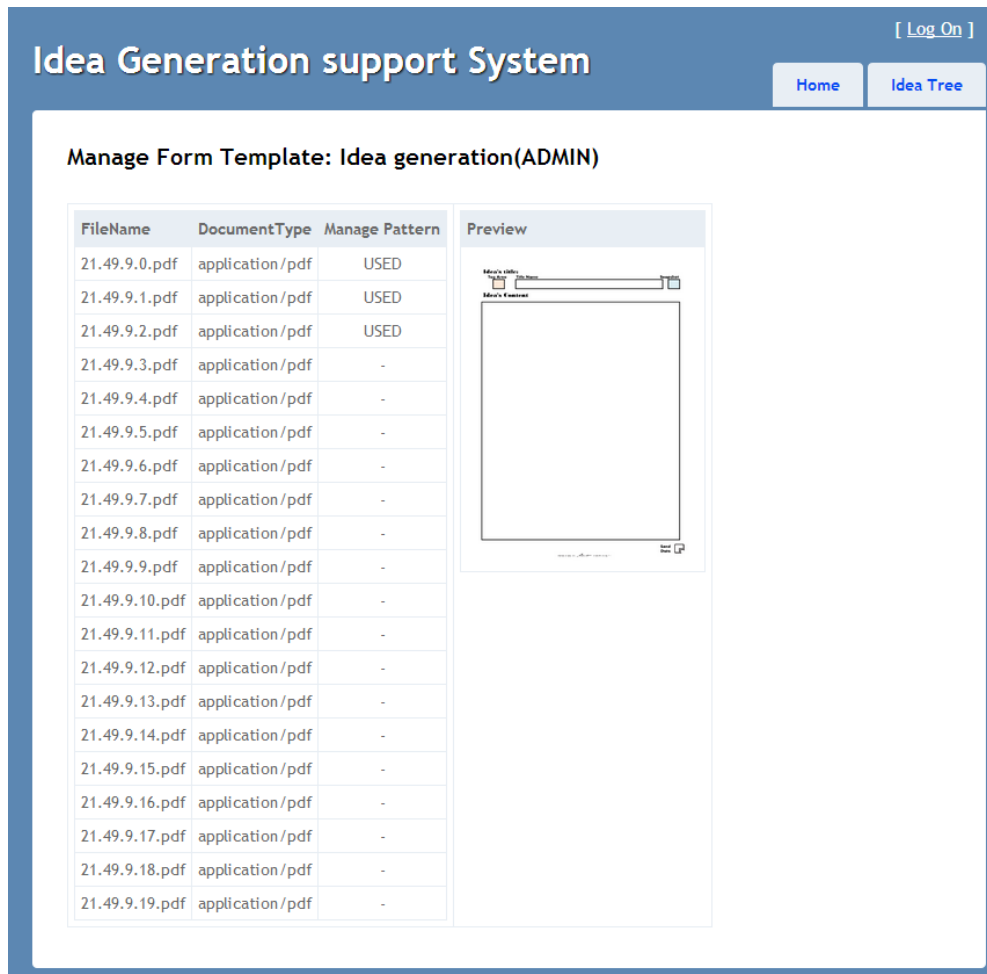
Figure 4-9: Application page of Pattern management function (ADMIN's view)

4.4   Design data collection tool

Data collection tool was implemented to help convert and store handwritten data as log data in our designed database schema. The data collection tool is written as a .NET WinForm Application (C#), utilizing API provided by digital pen SDK to access to handwritten data. As illustrated in Figure 4-10, the flow for processing and storing handwritten data starts when users perform check on "Send data" command box. Data stored in digital pen then will be transferred via Bluetooth to nearby PC and temporary stored in XML format. When data transferring from digital pen to PC is completed, data collection tool will be triggered automatically to perform further data processing and storing data on server by utilizing digital pen API to access to the temporary stored handwritten data. Upon complete storing data in our designed database, data collection

tool will delete the temporary stored data from users PC.
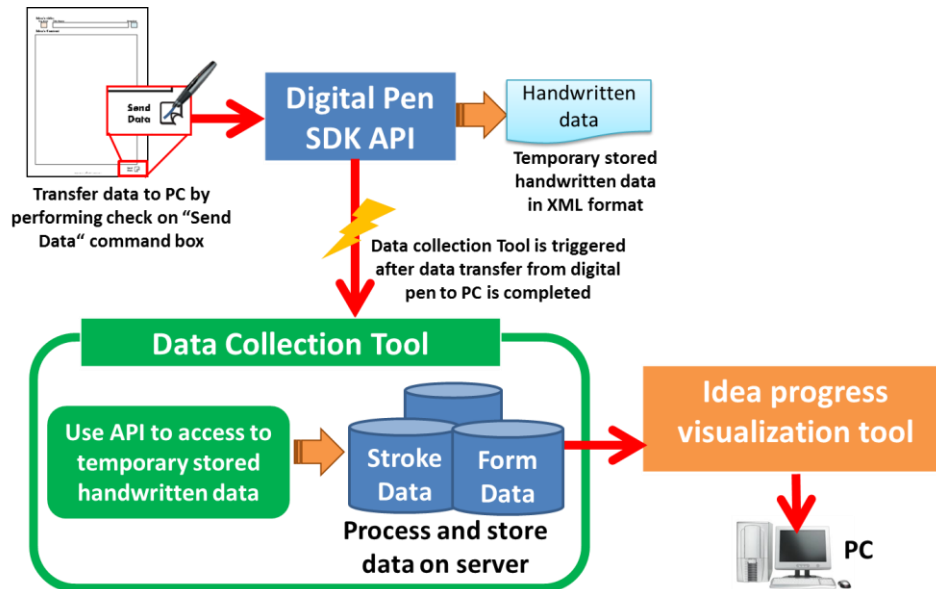
Figure 4-10: Flow for processing and storing handwritten data on server

While performing data processing, data collection tool will show the program progress as illustrated in Figure 4-11.
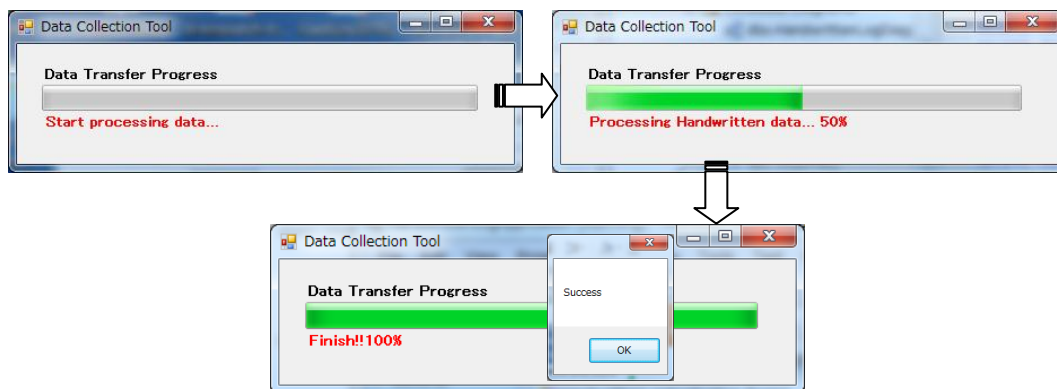
Figure 4-11: Application screen of Data collection tool

4.5   Design idea progress visualization tool

We implemented idea progress visualization tool as an ASP.NET MVC application which can be accessed via web. The implementation of idea progress visualization is divided into 2 phases according to previous defined research problems and proposed solutions explain in Chapter 1.

4.5.1　Develop interface for visualizing handwritten data in tree structure: Idea tree

As mention above, due to difficulty for tracking alternatives and changes occur during idea generation progress with traditional notes paper, we proposed to utilize digital pen and paper interface for visualizing handwritten data in tree structure. We will call this as "Idea Tree", which refers to handwritten data visualized in tree structure.

Visualizing idea progress in digital paper as Idea Tree

We utilize digital pen and paper to provide information such as stroke data (ex. coordination of handwritten data and written time) and form data (ex. name of field area in the form stroke data has been written) for visualizing them in tree structure. Figure 4-12 shows how handwritten data on digital paper will be visualized in tree structure.

Figure 4-12: Handwritten data on digital paper and visualized data in tree structure

Process for visualizing handwritten data in digital paper as Idea Tree can be summarized as followed.

- Show handwritten data in Idea Title's field as the first branch of Idea Tree.

- Show handwritten data in Idea Content field as the following branches. Further divide them into several sub-branches to represent snapshot of stroke data in order of writing time (example of Idea Tree in Figure 4-12 represents 3 snapshots of stroke data).
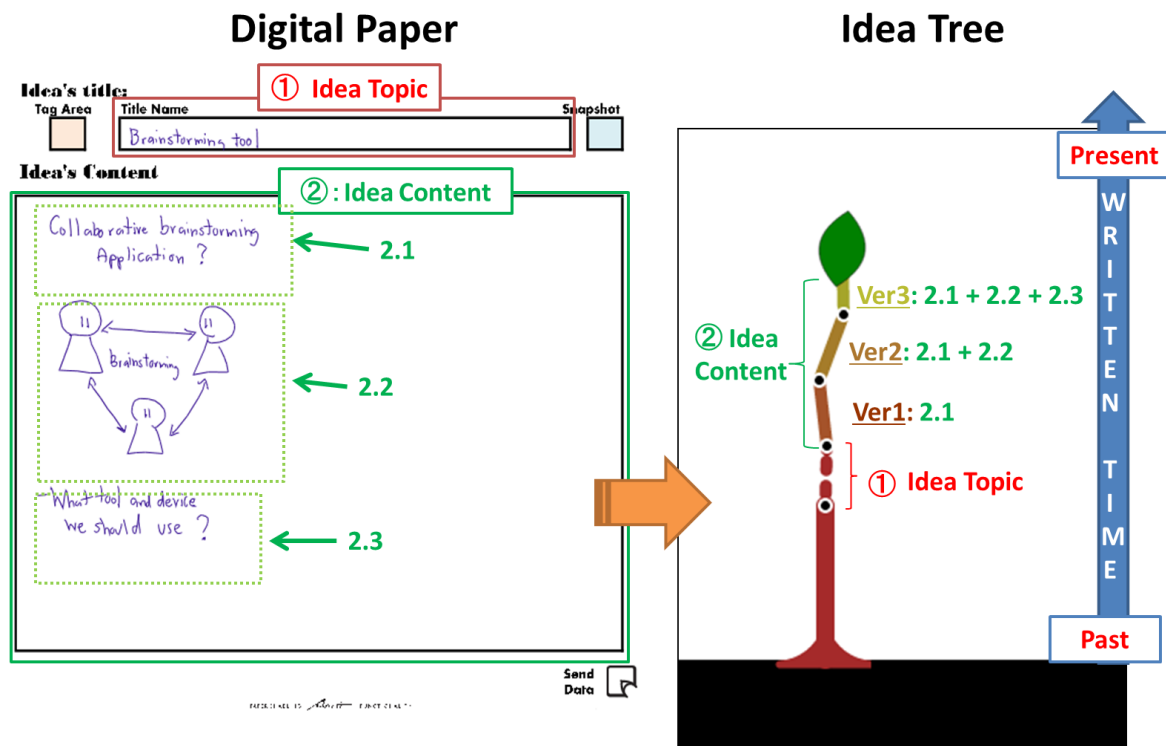- Show image of tree's leaf on the final branch as the latest version of handwritten data.

Representing handwritten data in Idea Content's field as several snapshot version of stroke data was done to help improve visualization of changes occurs during idea generation progress. As shown in Figure 4-12, stroke data in Idea Content field are divided into 3 groups, each represent as sub-branch of idea topic. Dividing and Grouping of stroke data in Idea Content's field can be done both automatically and manually. Figure 4-13 illustrated how handwritten are grouped together automatically by utilizing pause time of digital pen. The example shows that if users wrote the content "Collaborative brainstorming Application?" and stopped writing for more than 5 seconds and then continued to write again, data will be grouped accordingly as shown below.
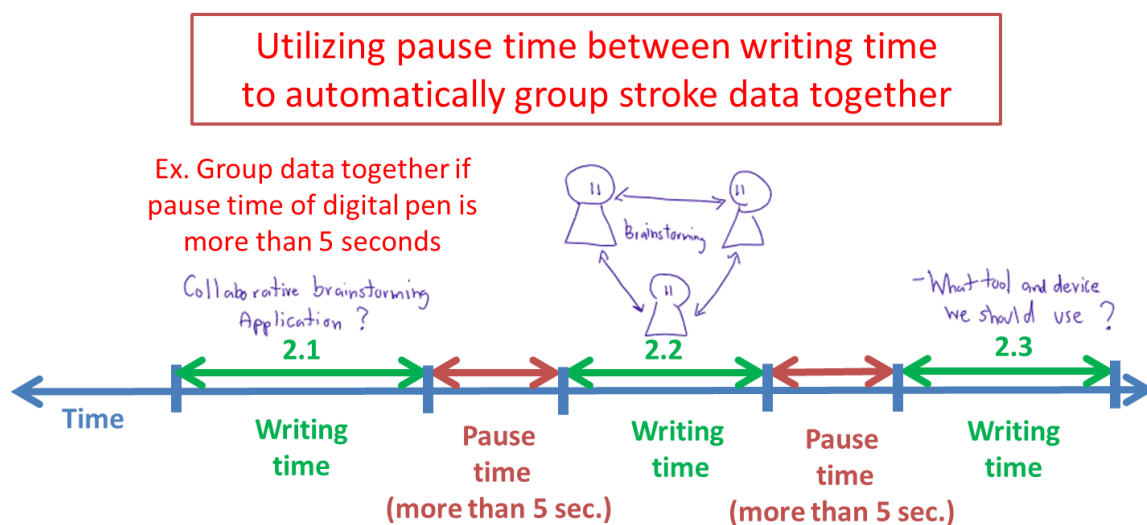

Figure 4-13: Utilizing pause time of digital pen to automatically group stroke data

The process of grouping data together is done by data collection tool. Table 3 shows example of processed handwritten data stored in our designed database used in rendering Idea Tree in Figure 4-12.

Table 3: Processed handwritten data for visualizing Idea Tree

IdeaTitle Table				
ID	Page Address	Time	fk_ StrokeDataID	...
10	21.49.9.0	2013-01-02 16:33:47.483	516	...

StrokeData Table		
ID	StrokeCount	...
516	22	...
517	48	...
518	36	...
519	33	...

IdeaContent Table					
ID	Page Address	Time	fk_ IdeaTitleID	fk_ StrokeDataID	...
200	21.49.9.0	2013-01-02 16:34:02.517	10	517	...
201	21.49.9.0	2013-01-02 16:34:31.647	10	518	...
202	21.49.9.0	2013-01-02 16:35:16.720	10	519	...

As shown below, IdeaContent Table consists of 3 records of data; each has foreign key ID point to IdeaTitle and StrokeData Table (StrokeData Table contains number of stroke of grouped data which is further point to table contains x-y coordination and written time of stroke data (ex. Stroke Table and PointData Table).

Grouping of handwritten data in Idea Content's field can also be done manually as well by using "Snapshot" command box in the top right corner of the form template in digital paper. Using this paper-based interface, users can achieve the same result by performing action as shown in Figure 4-14.
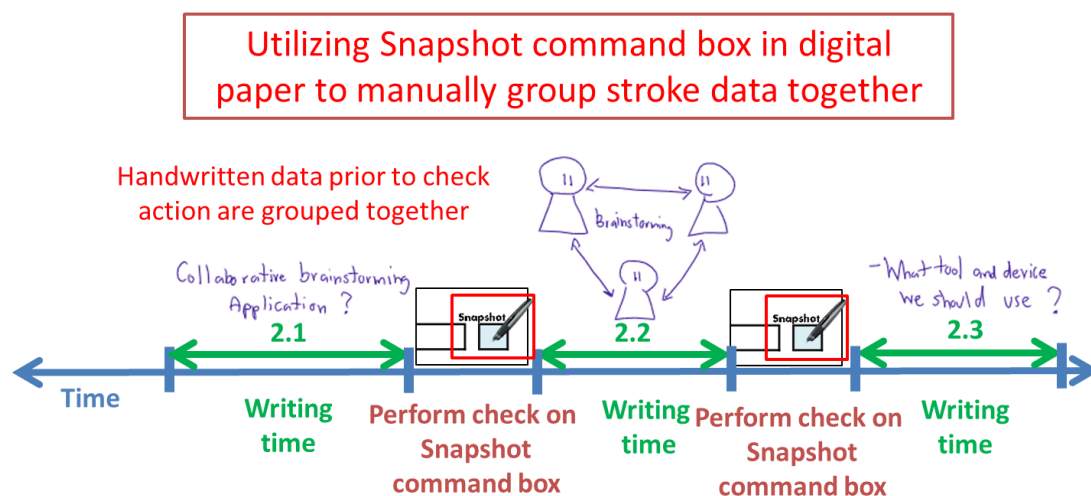
Figure 4-14: Utilizing snapshot command box in digital paper to group stroke data

Both automatically and manually grouped stroke data will be used to represent snapshot version of stroke data in Idea tree as shown in Figure 4-15. For example, the first sub-branch of Idea Tree in Figure 4-12 contains groups of stroke data written up to snapshot version1. The second sub-branch contains handwritten data up to version2 and the last branch up to version3.
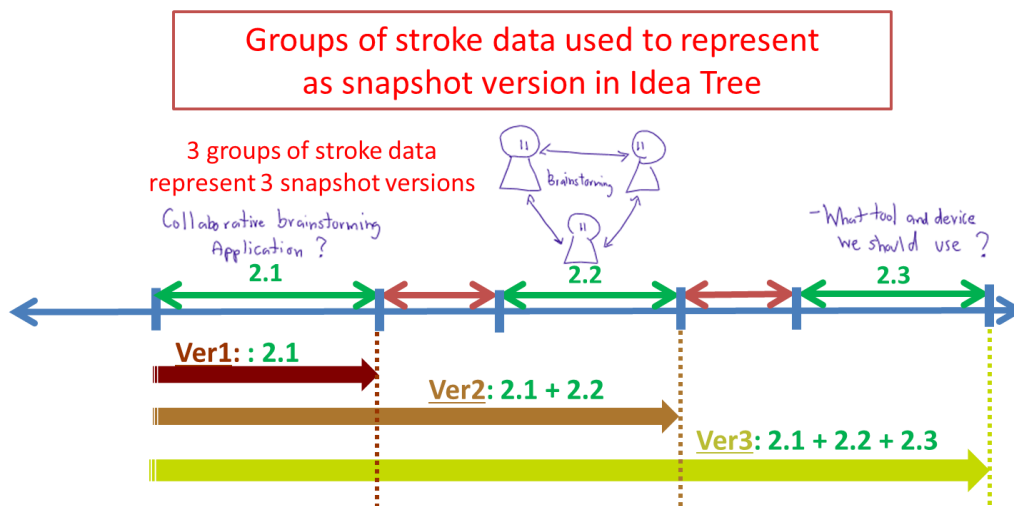
Figure 4-15: Snapshot version data shown in Idea Tree

Visualizing handwritten data according to idea's topic

Idea Tree can also be used to help users track progress of multiple ideas generated during idea generation progress as well. As shown in Figure 4-16, we utilize digital pen and paper to re-organize and group handwritten data according to their topics. Each handwritten data that belongs to different idea's topic will be shown in different branches. Each of those branches further contains sub-branches which represent idea data written in Idea Content's Field.
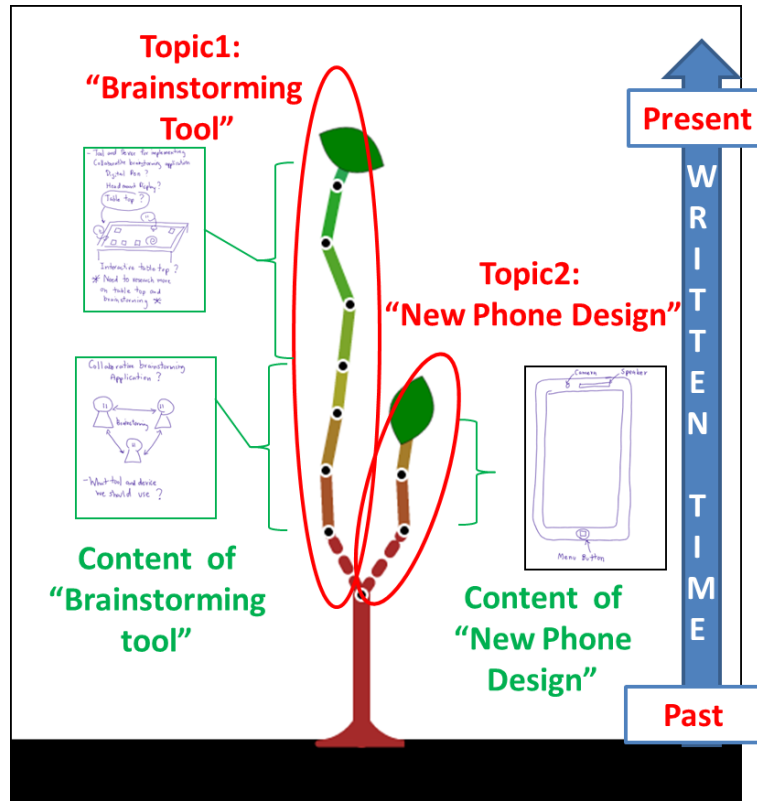
Figure 4-16: Utilizing Idea Tree to tracking idea progress by topics

To achieve visualization of Idea tree in Figure 4-16, we provide interface for grouping handwritten data to a particular topic by utilizing data provided by digital pen and paper. Figure 4-17 shows example of how handwritten data can be grouped automatically. First, users wrote idea topic about "Brainstorming tool" in "Idea Title" field and then wrote content in "Idea Content" field. The following day users generated new idea about "New Phone Design" and wrote about it in the new page. In this case, each handwritten data in "Idea Title" field will be automatically assigned as idea's topic of data written in "Idea Content" field of the same page.
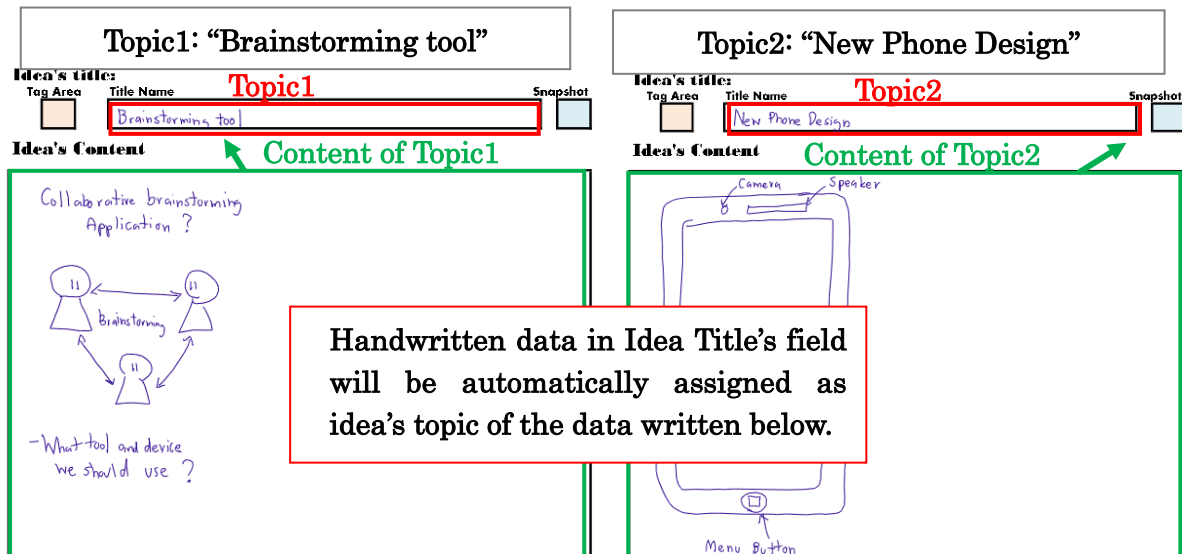
Figure 4-17: Automatically assigns different idea topic to handwritten data

To manually assigned topic to idea's content, users are required to use command box in our designed digital paper's form template. Figure 4-18 shows example of case that users continue to write more ideas about "Brainstorming tool" in different page and need to group those data together as same idea's topic as previous written data. Topic can be assigned manually by performing check on "Tag area" located next to idea topic users want to be grouped with before continue to write ideas on new page. New handwritten data will be displayed as new sub-branches of "Brainstorming Tool" as shown in Figure 4-16.
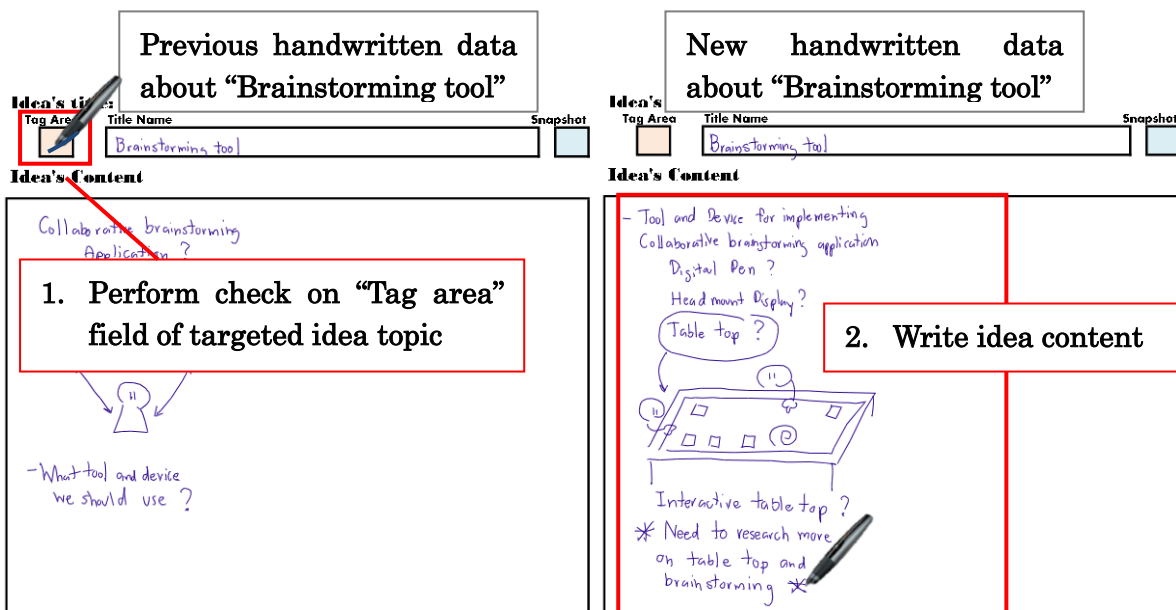
Figure 4-18: Manually assigned idea topic by using command box on digital paper

Application page and interfaces for tracking idea progress

Visualized handwritten data explained above can be viewed through our "Idea Tree application page" shown in Figure 4-19. This page can be accessed by clicking on the "Idea Tree" button displayed in the top right of the application page.
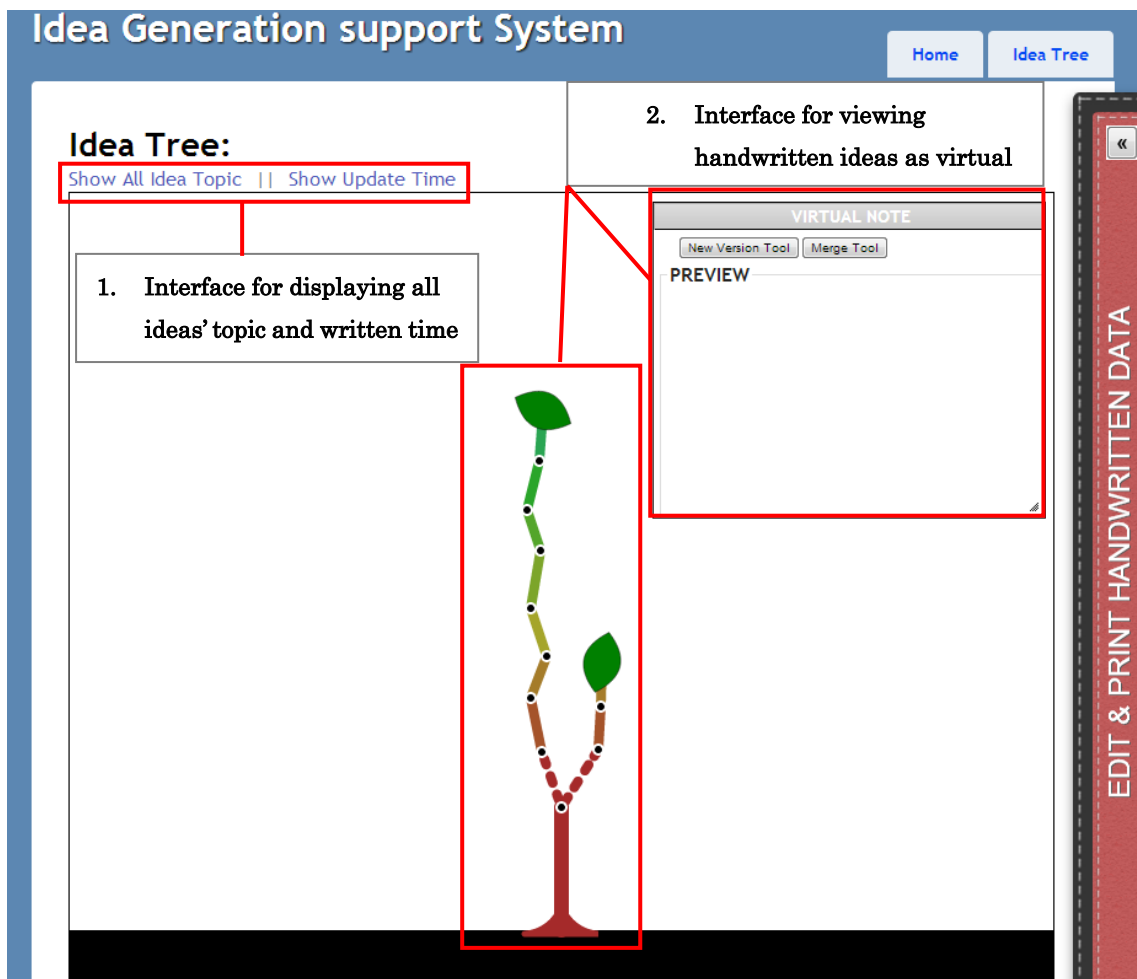
Figure 4-19: Application page and interfaces of Idea Tree

Idea Tree application page is used to offer the following interfaces.

1. **Interface for displaying all idea's topics and update time:**

   This interface allows users to view all written ideas' topic and the latest update time of each topic. They will be shown as virtual note which users can show or hide by clicking on the link "Show/Hide All Idea Topic" and "Show/Hide Update Time". As shown in Figure 4-20, when users click on "Show All Idea Topic", handwritten data in

Idea title's field will be shown as ideas' topic above the tree's leaf. If users click on "Show Update Time" as well, the latest written time of handwritten data in Idea Content's field that belongs to each topic will be displayed above the tree's leaf.

Figure 4-20: Interface for displaying all written idea's topics

2. Interface for viewing handwritten data as virtual note:

This interface consists of first, Idea Tree used for selecting handwritten data and second, Virtual Note window used for rendering handwritten data. HTML5 canvas and open source vector graphic framework called Paper.js[8] are used to create interactive vector animation (such as for virtual note). To make tree structure layout more compact, we implem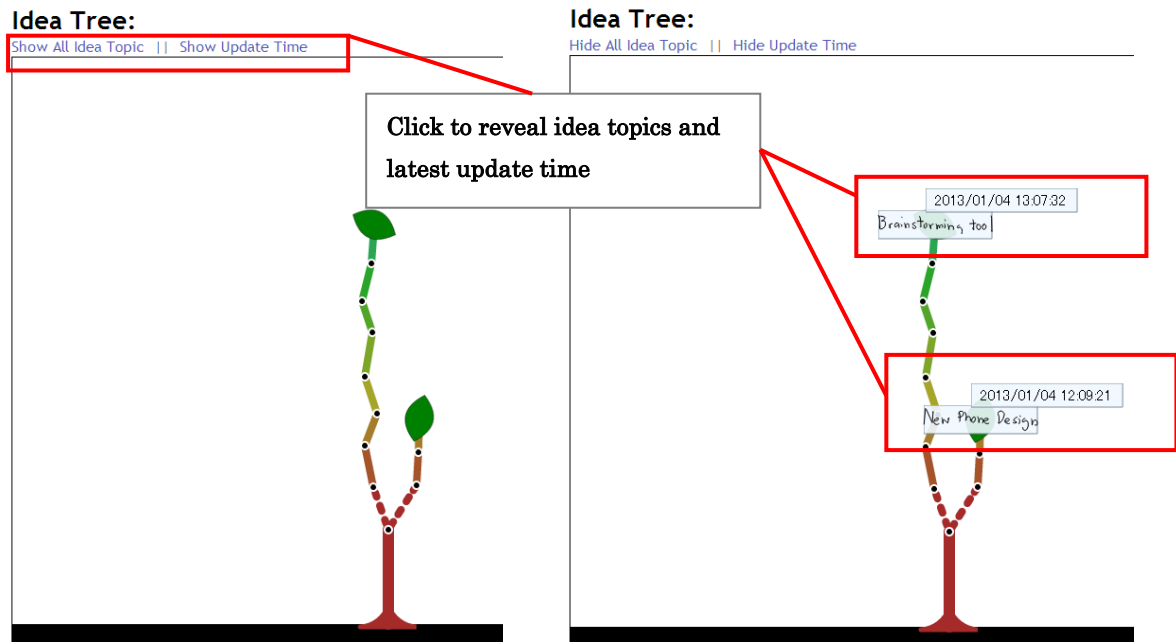ented Walker algorithm[9] to help calculate position of x and y-coordinate for each node in the tree structure. We also used jQuery in implementing "Virtual Note" window to make it resizable and movable.

When users perform mouse over on Idea Tree's branch and leaf, AJAX script will be executed to perform SQL query in background for retrieving and rendering stroke data of virtual note. We used Paper.js framework to help detect hit event and identify hit object, which contain properties such as object's name (ex. leafObj, branchObj) and index data used as condition parameter for retrieving stroke data (ex. ID value of IdeaTitle table, IdeaContent table). Retrieved data is passed back in JSON format which contains information such as written time and x-y coordination of stroke data. After successful retrieving data back, canvas will update and render them as snapshot of handwritten data version in Virtual Note window.

<u>Perform mouse action on Idea Tree's branch:</u>

As shown in Figure 4-21, when users perform mouse over action on Idea Tree's first branch, hit event will be detected and hit object will be highlighted in red color. Since first branch's object only represents group of stroke data for idea's topic only, Virtual Note window is updated to show only handwritten data of idea topic (Brainstorming tool) and written time of idea topic (2013/01/02 16:33:58).
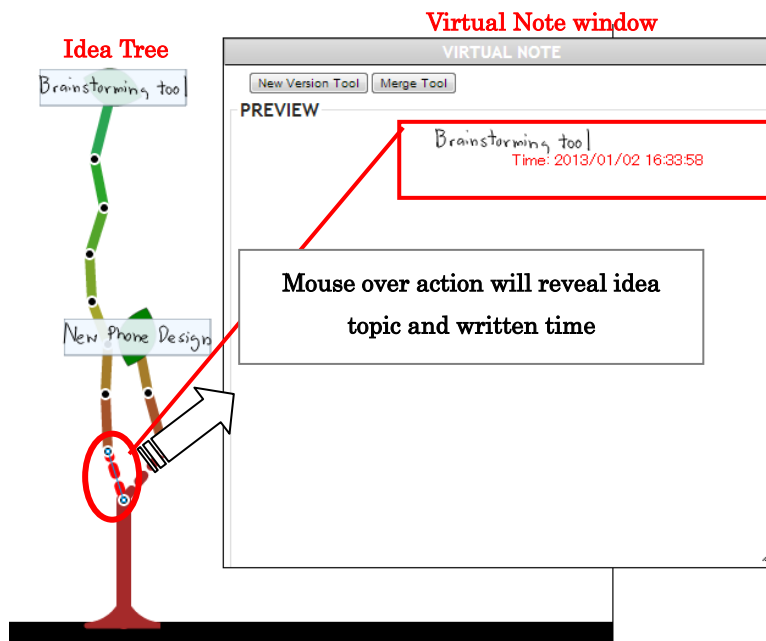

Figure 4-21: Perform mouse over action on Idea Tree to display idea topic and written time

If the branch object used for representing idea content is hit, Virtual Note window will display groups of stroke data up to that snapshot version. For example, figure 4-22 illustrates case that if users perform mouse over action on the second sub-branch.
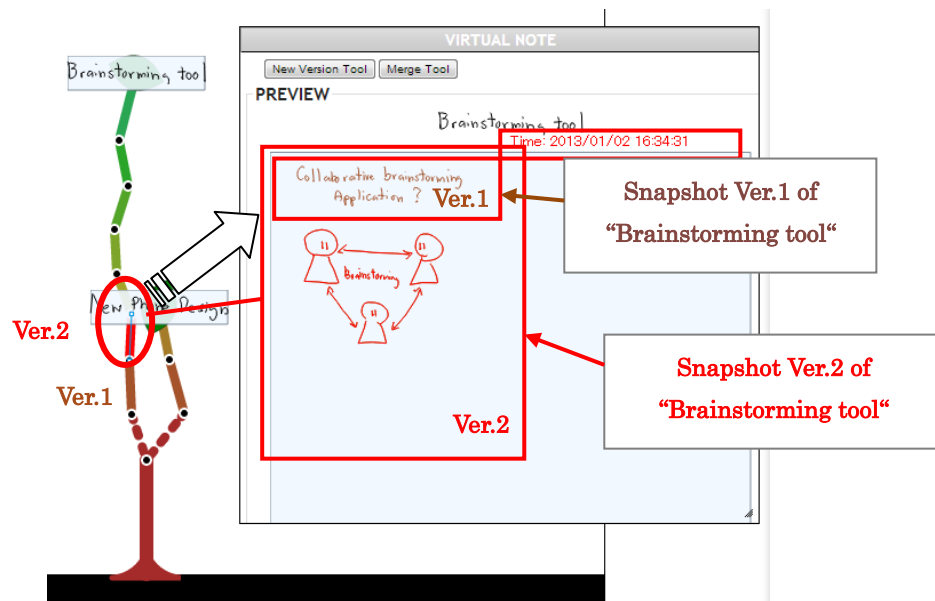
Figure 4-22: Mouse over to display stroke data up to selected snapshot version

Stroke data up to snapshot version2 (groups of stroke data written prior to time of 2012/01/02 16:34:31) will be shown in Virtual Note. Same color of Idea tree branch will be used to display stroke data of that snapshot version (ex. brown color for version1, red for current selected version)

Perform mouse action on Idea Tree's leaf:

As shown in Figure 4.23, when users perform mouse over action on Idea Tree's leaf, all sub-branches that belong to the same idea's topic will be highlighted in red color. Virtual note of the page that has latest update time of idea's content will be displayed, showing latest snapshot version of that page. Users can perform double click on leaf to un-highlight the color of stroke data and Idea's tree branch.
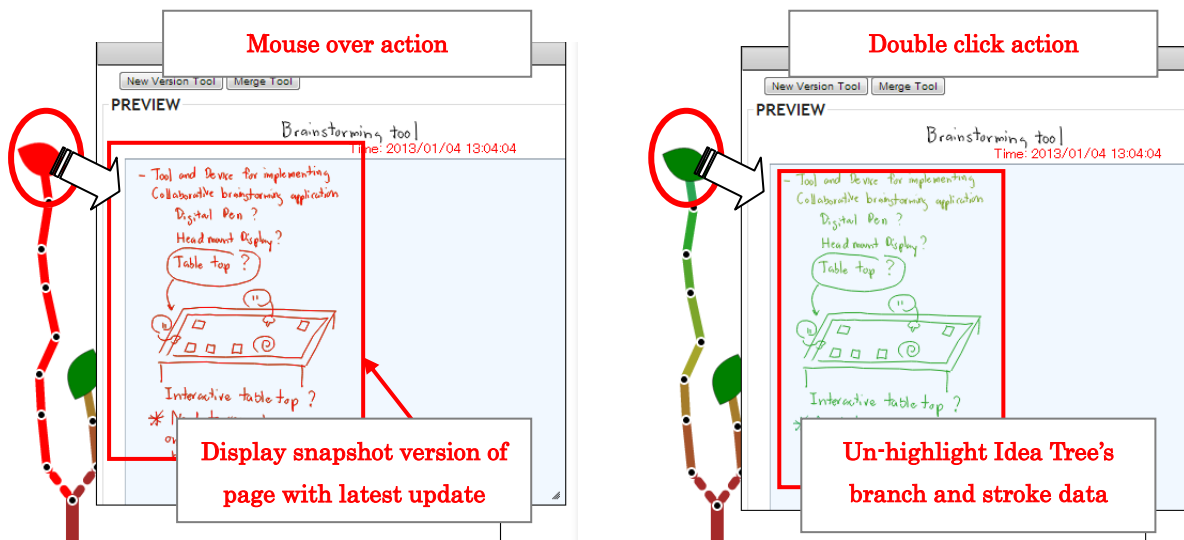
Figure 4-23: Mouse action performs on leaf object

4.5.2 Develop interface for reusing past version of handwritten data

As defined above, handwritten data in traditional note poses problem due to its limited reusability. To solve this problem, we designed interfaces that users can print past snapshot version of handwritten data and reuse them to explore new ideas and alternatives.

Interfaces for reusing past version of handwritten data

Interfaces for reusing past version of handwritten data are implemented on Idea Tree application page. According to functionality and role they offer, we have divided interface for reusing version as followed.

1. **Interface for creating new alternatives from past generated idea**
This interface offers functionality for users to go back to past snapshot version of written idea data. Users can print them out on digital paper and reuse them as based-version for creating new alternatives. Overview of this interface is illustrated in Figure 4-24.
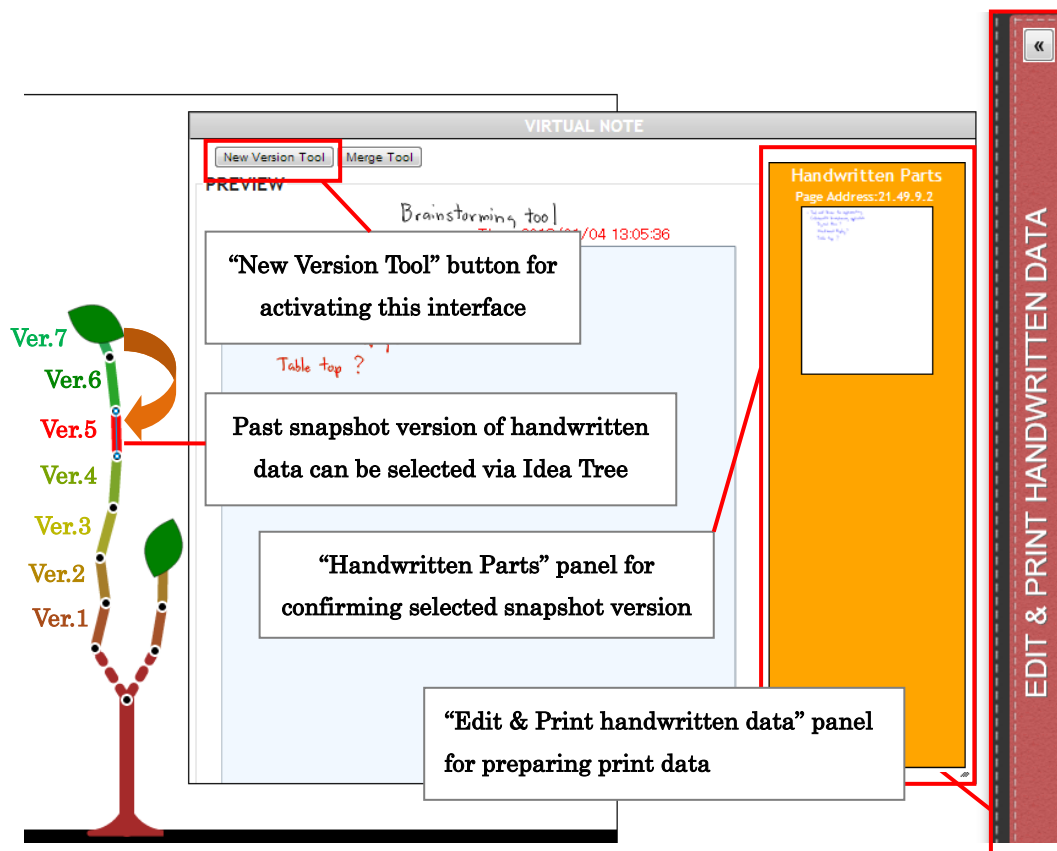
Figure 4-24: Interface for creating new alternatives from past generated idea

Figure 4-25 illustrates case that users need to revert back to past snapshot version of generated idea. For example, users need to explore new alternatives about utilizing "digital pen" as tool for implementing collaborative brainstorming application. Users also want to reuse the past snapshot version up to the point ideas about "interactive table top" haven't been written yet. In this case, users will need to revert back to snapshot version 5. To print and reuse it as based version for creating new ideas about digital pen.
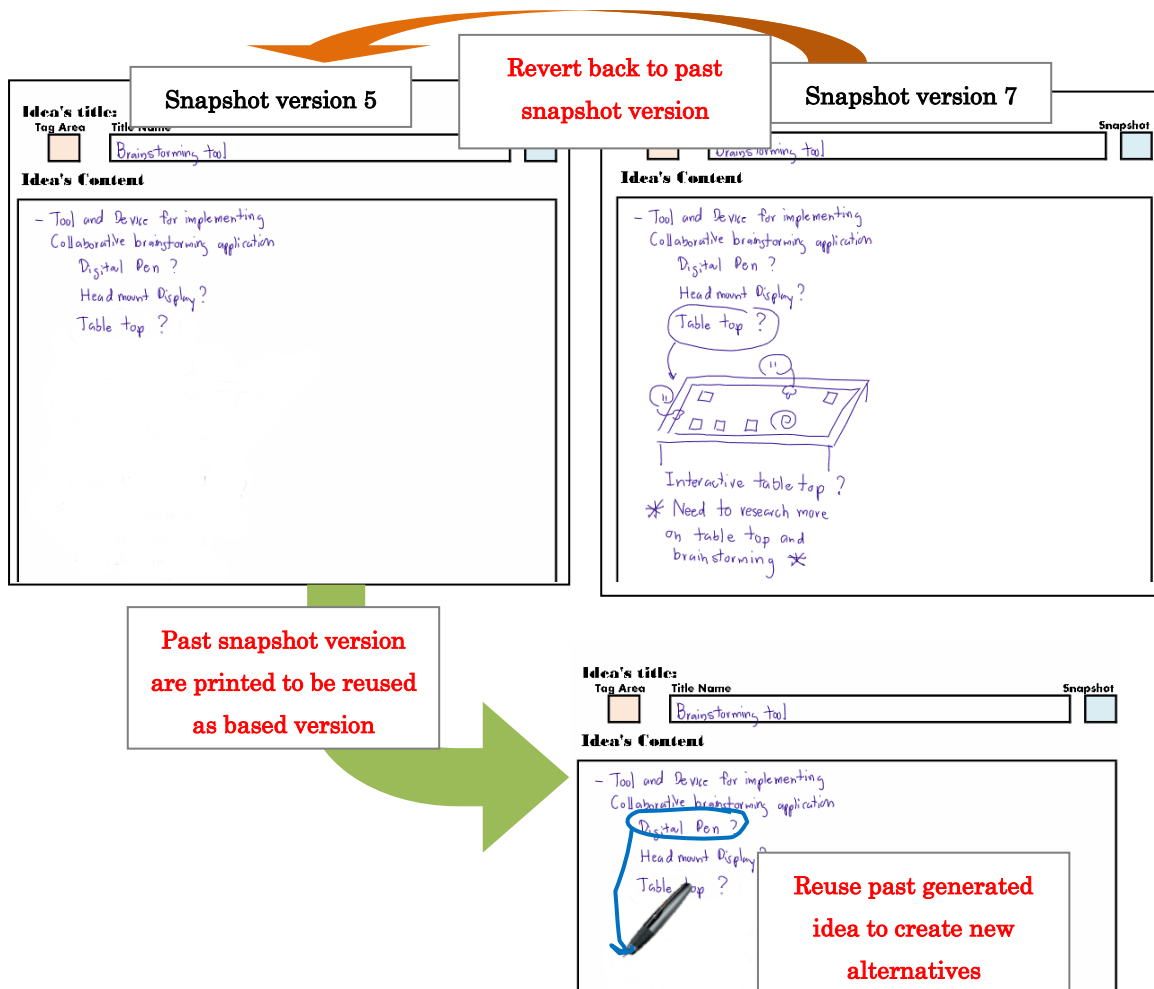
Figure 4-25: Printing past snapshot version of handwritten data

To achieve this, first users are required to activate this interface by clicking on the "New Version Tool" button on Virtual Note window. As shown in Figure 4-26, after activating this interface the instruction's dialog window will be displayed to show further instruction to user. The "New Version Tool" button will also be changed to display "Finish select" button instead. Users can perform mouse over on Idea Tree's branch to view past snapshot version of handwritten data on Virtual Note window.
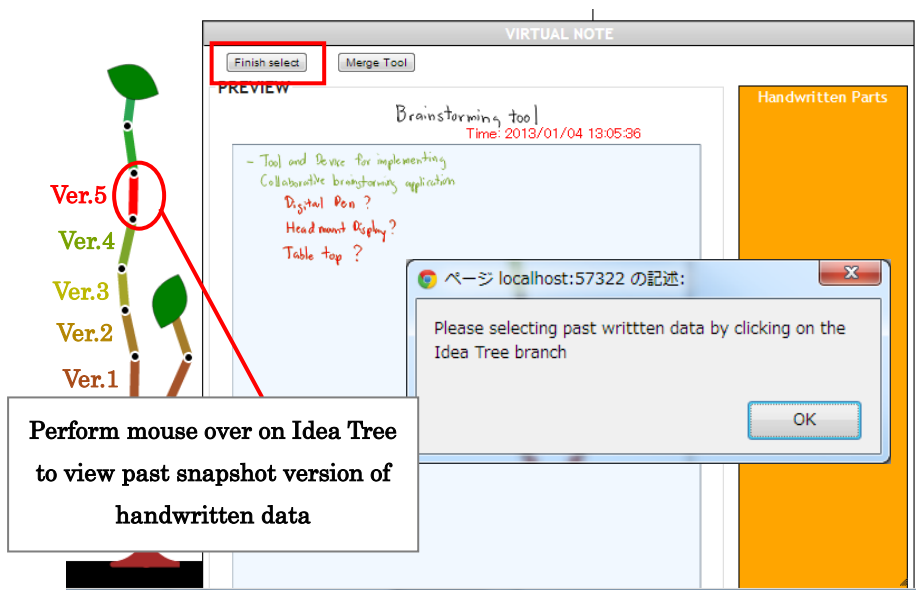
Figure 4-26: New Version Tool and Idea Tree

Selection of past snapshot version can be performed by clicking on the Idea Tree branch. As shown in Figure 4-27, after users selected snapshot version 5, past handwritten data up to that version will be highlighted in red color. The selected snapshot version will be shown in "Handwritten Parts" panel.
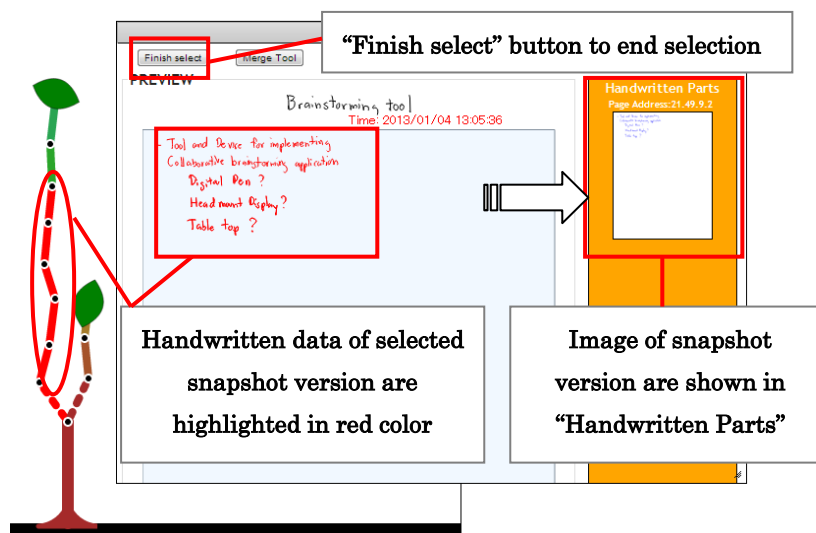
Figure 4-27: Selecting past snapshot version of handwritten data

After users click on "Finish select" button to end selection, "Edit & Print Handwritten data" panel will be animated to slide over to the left as shown in Figure 4-28. This panel

consists of 2 areas, which are Snapshot area and Virtual Note area. Users can use this panel to generate print data of past snapshot version.

Figure 4-28: Generate print data through "Edit & Print Handwritten data" panel

Snapshot area contains image of selected snapshot and button used for generated print data. Virtual Note area is used to display handwritten data of the selected snapshot version. To print out the selected snapshot version of handw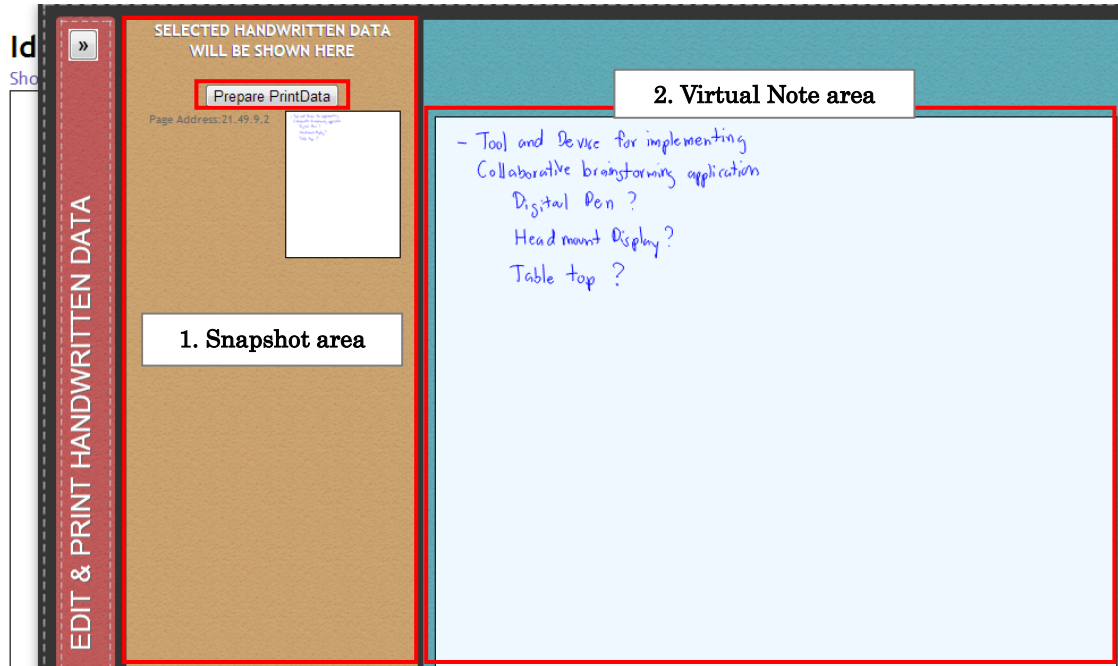ritten data, users are required to click on "Prepare Printdata" button which will trigger request to server to perform necessary process for generating digital paper with past snapshot version of handwritten data. Process for generating print data can be summarized as followed.

- Generate base64 encoded string of image data from Virtual Note area by using canvas function
- Send Ajax request containing image data to server to create image file in PNG format
- Execute shell command to generate A4-size PDF file from PNG image file (utilizing an open source imaging library called Imagemagik [21])
- Use Pattern Management Function to retrieve next available pattern data, generate it as pattern file in PDF format
- Execute shell command to generate PDF file of overlay pattern file with image of handwritten data (utilizing an open source pdf library called PDFTK [22])

- Update PatternData Table and Insert new record into ManageVersion Table
- Send URL link of generated PDF file back to client, reload page
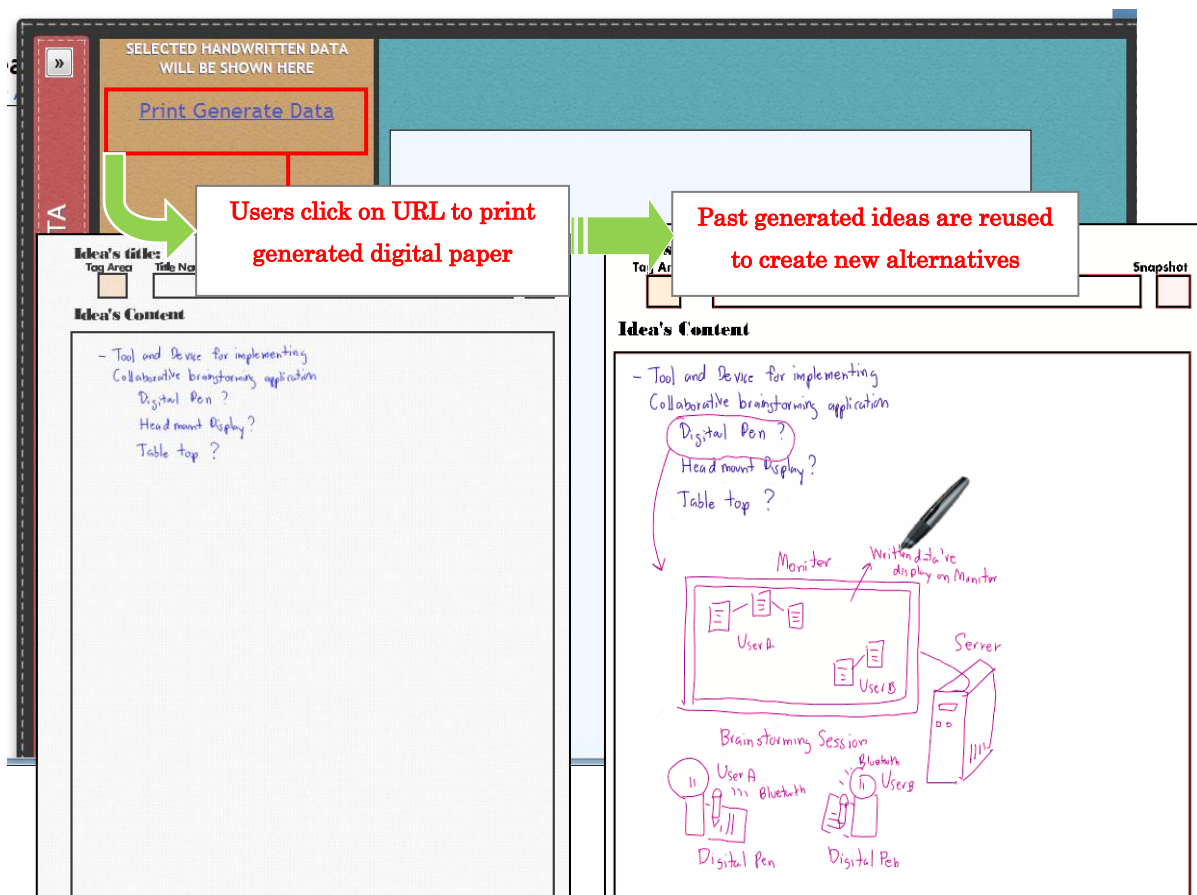
Figure 4-29: Print and reuse past generated ideas for creating new alternative

When process of generating digital paper is completed, Idea Tree application page will be reloaded to display link of generated print file as shown in Figure 4-29. Users can click on "Print Generate Data" link to download generated digital paper file in PDF format and print it out. As shown above, past handwritten data are reused as based version for users to write new alternative about utilizing digital pen for collaborative brainstorming. These newly created handwritten data then will be visualized in Idea Tree as new snapshot version of handwritten data as shown in Figure 4-30.

Since users had created new version from past snapshot data version 5, Idea Tree will display it as new sub-branch from that snapshot version. Figure 4-30 shows example of when users perform mouse over action on branch object of pervious and new snapshot version for idea about "Brainstorming tool". In Virtual Note window of new snapshot,

handwritten data which belongs to snapshot version up to version 5 will also be displayed in new version as well.
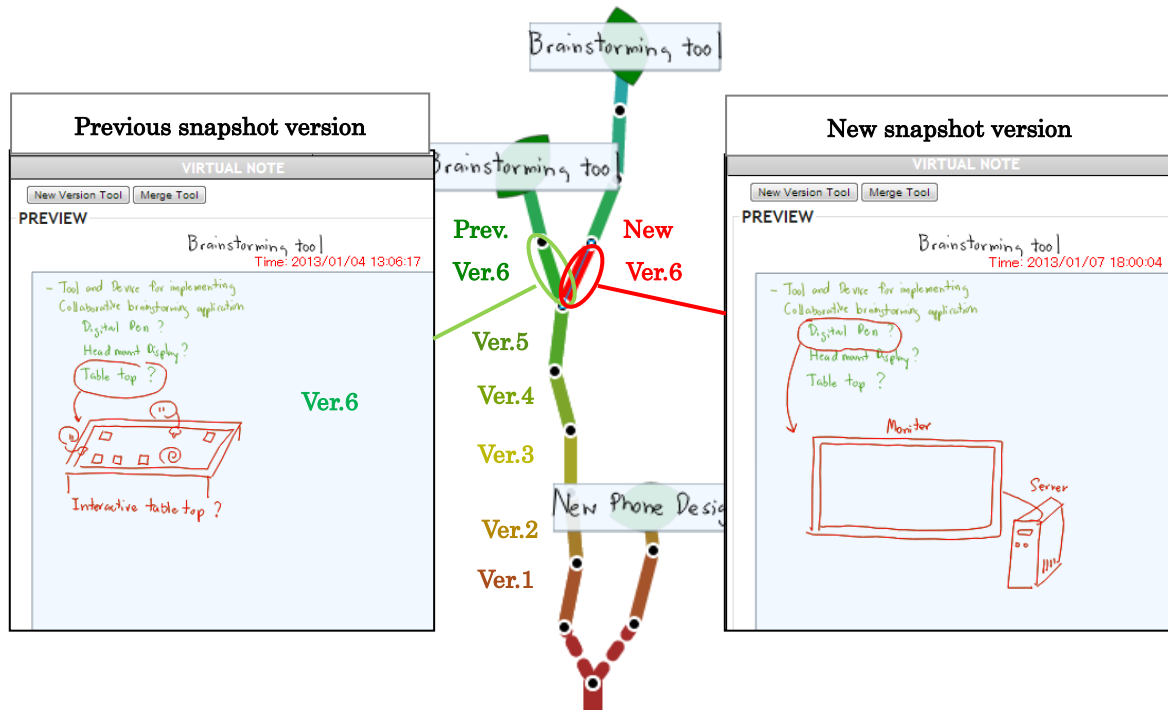
Figure 4-30: New snapshot version shown in Idea Tree

Thus, by offering the above interface for creating new alternatives of past generated idea, we hope to improve reusability of past handwritten data as well as help visualize changes and track idea progress.

2. Interface for combining past generated ideas as new idea

With our provided interface, handwritten data can be selected and merged together to generate print data that users can write with digital pen. As shown in Figure 4-31, we use Idea tree to provide interface for combining past generated ideas together and reuse them as based version for creating new idea. In this example, users reuse multiple past generated ideas which are stored in our database as groups of stroke data. Stroke data of Ideas about "Hero Character Design" and "Monster Character Design" are combined together to help in creating new character design.

Figure 4-31: Reuse multiples generated ideas as based version

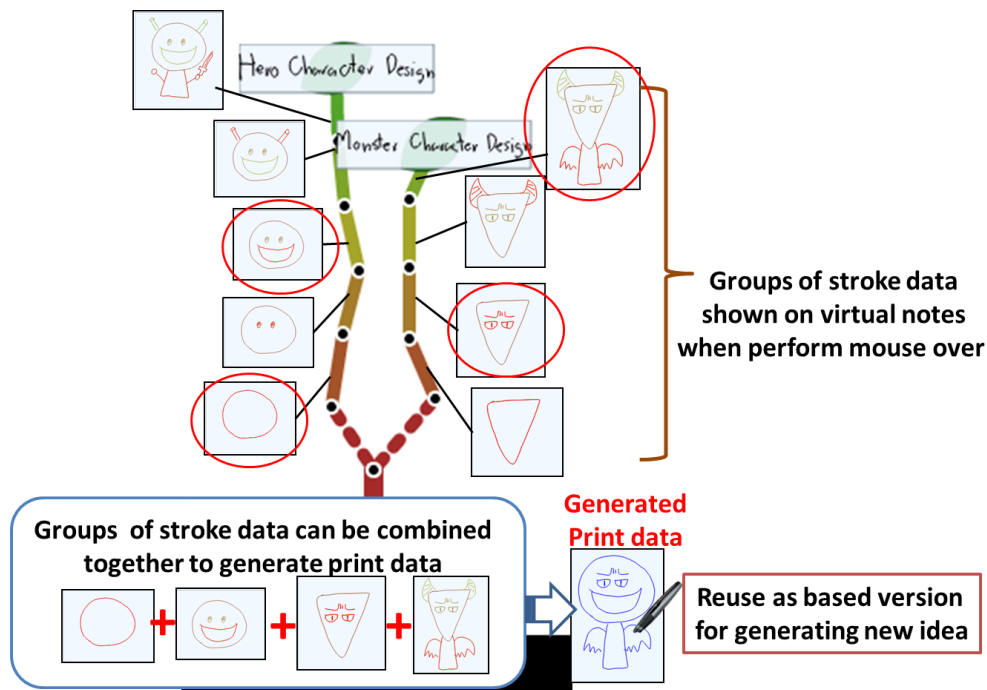Overview of interface for combing past generated ideas can be illustrated in Figure 4-32.
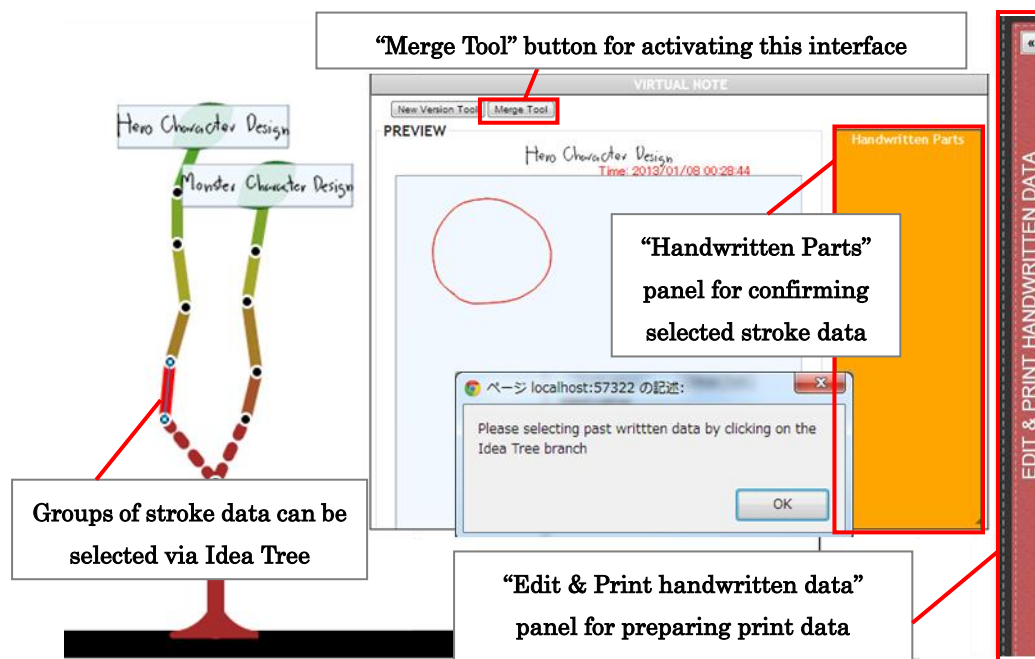

Figure 4-32: Interface for combining past generated ideas

First, users required to click on "Merge Tool" button to active this interface. Users can confirm groups of stroke data to be reused by performing mouse over action on Idea Tree's branch. Stroke data to be reused will be highlighted in red color and shown in Virtual Note window. To select groups of stroke data to be reused, users will need to perform mouse click action on Idea Tree branch.

As shown in Figure 4-33, after users perform mouse click action on Idea Tree, the selected stroke data and branch will be highlighted in red color. Image of selected stroke will be added to Handwritten Parts panel on the right. Users can select multiple groups of stroke data to be reused by clicking on different Idea's Tree branches.
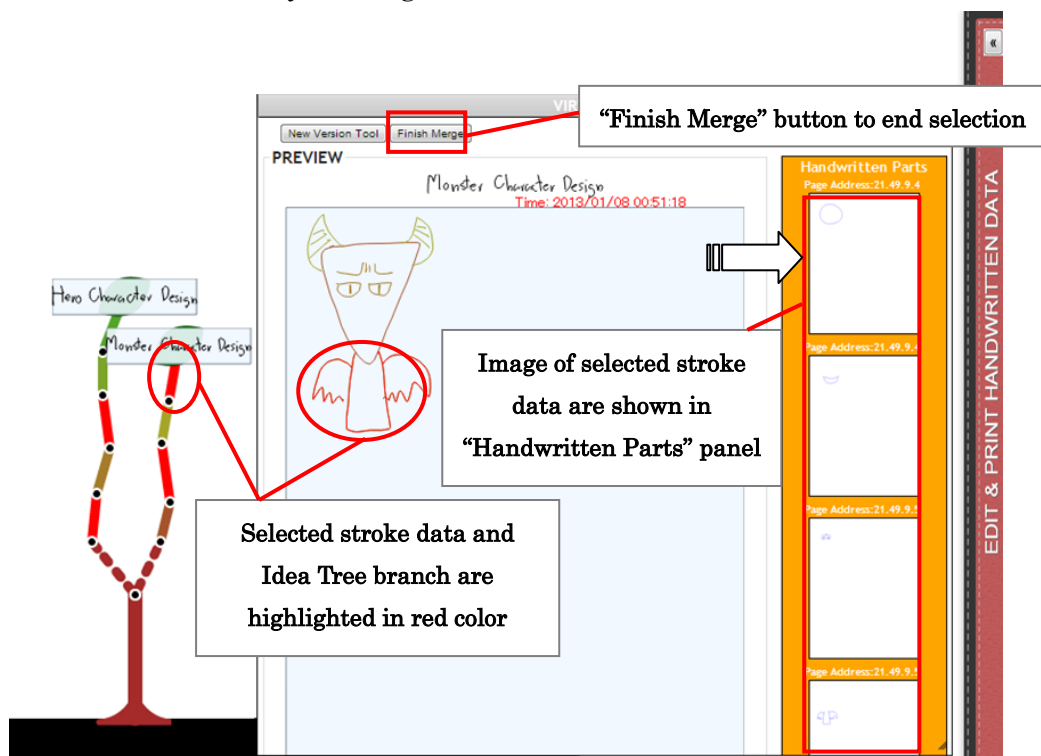
Figure 4-33: Selecting groups of stroke data to be reused

After users click on "Finish Merge" button to end selection, "Edit & Print Handwritten data" panel will be animated to slide over to the left as shown in Figure 4-34. This panel consists of 3 areas, which are Snapshot area, Toolbox area and Virtual Note area. Snapshot area contains image of selected stroke data and button used for generated print data. Toolbox area consists of tool used for editing handwritten data before generated print data. Virtual Note area is used to display groups of selected stroke data. Stroke data display in this area can be selected and moved by using Move tool. Enlarge tool and Shrink tool are used to increase and decrease size of handwritten data.

Figure 4-34: Prepare print data through "Edit & Print Handwritten data" panel

To print out the selected stroke data, users are required to click on "Prepare Printdata" button. It will trigger request to server to perform necessary process for generating digital paper with groups of stroke da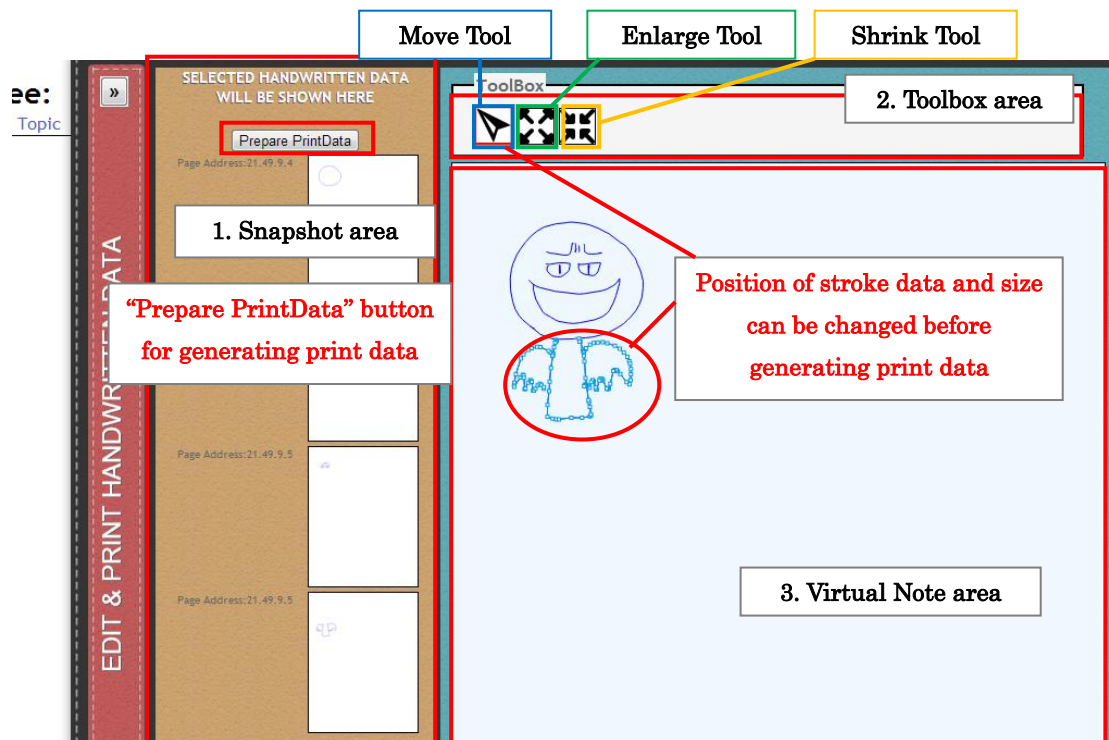ta printed above. Process for generating print data is similar to previous explained interface, which image data on Virtual Note area and next available pattern data are used for preparing print data. After print data finished being generated, system will update PatternData Table and insert new record into IdeaTitle Table and IdeaContent Table.

When process of generating digital paper is completed, Idea Tree application page will be reloaded to display link of generated print file as shown in Figure 4-35. Users can click on "Print Generate Data" link to download generated digital paper file and print it out. In this example, past handwritten data are reused as based version for users to write new idea about "Boss Character Design".
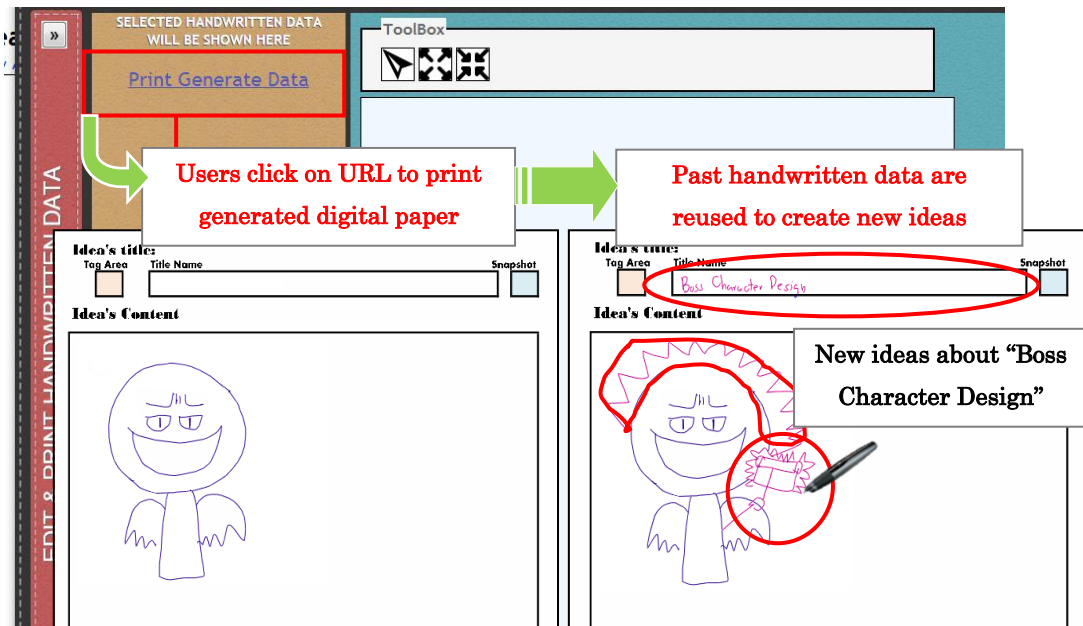
Figure 4-35: Print and reuse past handwritten data for generating new idea

These newly created handwritten data then will be visualized in Idea Tree as new branch as shown in Figure 4-36. Figure below shows example of when users perform mouse over action on leaf object of new idea about "Boss Character Design". In Virtual Note window, groups of stroke data which have been reused will also be displayed together with the newly created stroke data.
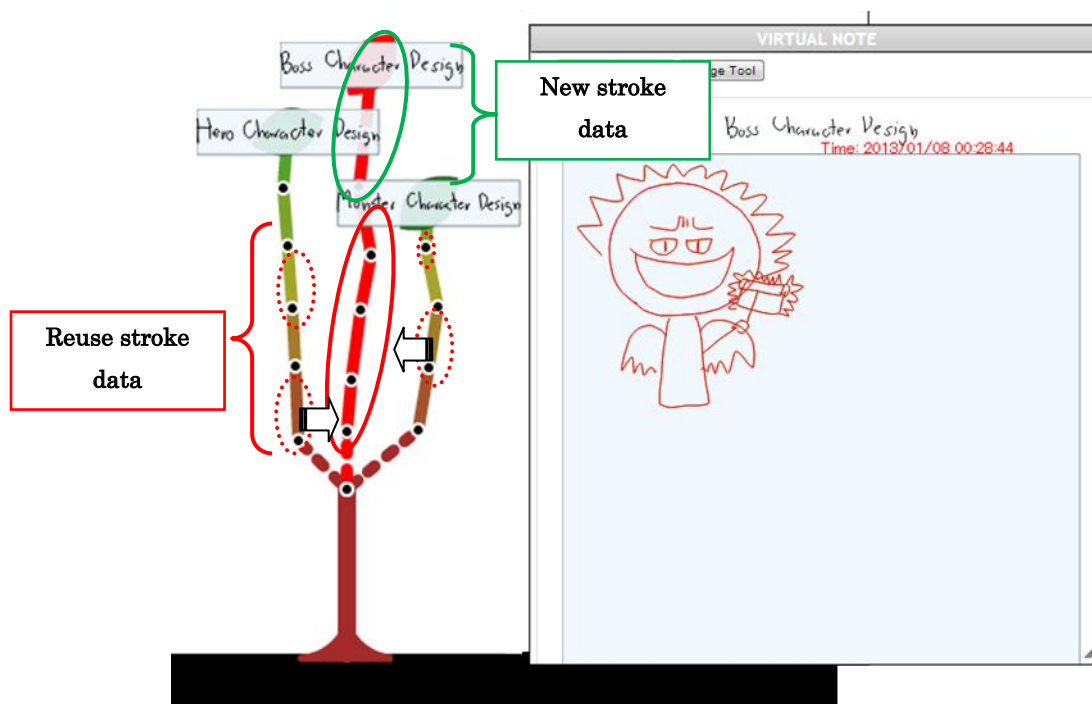
Figure 4-36: Combined stroke data shown as new idea in Idea Tree

Since this idea reused 2 groups of stroke data from idea "Hero Character Design" and 2 groups of stroke data from "Monster Character Design", sub-branches of those reused stroke data will be displayed in "Boss Character Design" as well (the next 2 sub-branches are displayed to represent newly created stroke data).

Utilizing the above interface, we hope to support users in idea generation process by allow them to combine past generated ideas together and reused them for exploring new alternative and refining ideas.

Chapter 5   Conclusion

In this paper, we propose an idea generation support system utilizing digital pen and paper technology to help individual user collect, manage, and keep track of idea generation progress as well as help improve reusability of past handwritten data. First, we developed data collection tool in order to store past generating ideas and alternatives in handwritten form. Then, we developed idea progress visualization tool, which used those store data to visualize writing activity in idea generation process in a tree structure form. By using this tool, we hope it could help support users in refining ideas and providing necessary visual aids for trigger clues or hint during idea generation process. Finally we also designed interface for reusing past handwritten data which combine paper-based interface with visualized Idea tree to help user explore new alternatives and refine ideas.

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