

# WordlePlus: Expanding Wordle's Use through Natural Interaction and Animation

Jaemin Jo, Seoul National University, Human-Computer Interaction Lab, [jmjo@hcil.snu.ac.kr](mailto:jmjo@hcil.snu.ac.kr)

Bongshin Lee, Microsoft Research, neXus Group, [bongshin@microsoft.com](mailto:bongshin@microsoft.com)

Jinwook Seo, Seoul National University, Human-Computer Interaction Lab, [jseo@snu.ac.kr](mailto:jseo@snu.ac.kr)



Figure 1: An animated creation of a wordle, showing a visual summary of Sara's research where “visual” and “analysis” are concatenated into the phrase “visual analysis,” “users” is merged into “user,” and “information” and “visualization” are grouped (see the “Interacting with WordlePlus” section). Words appear in three phases with the animation Sara chose.

## Abstract

In this paper, we open new possibilities of Wordle, a popular visualization technique. We present an interactive authoring tool called WordlePlus, which leverages natural interaction and animation. WordlePlus supports direct manipulation on words with pen and touch interaction, enabling more flexible wordle creation. It introduces new two-word multi-touch manipulation, such as concatenating and grouping two words, and provides pen interaction for adding and deleting a word. In addition, WordlePlus employs animation to amplify the strength of Wordle, allowing people to create more dynamic and engaging wordles. We also discuss challenges and future work in supporting kinetic manipulation and integrated interaction for pen- and touch-enabled tablets.

**Keywords:** Wordle, tag cloud, text visualization, pen and touch interaction, multi-touch interaction, animation, direct manipulation.

Wordle<sup>1</sup> has been commonly used to summarize texts with each word size-coded by its frequency of occurrences; the more often a word occurs in texts, the bigger the word is. Compared with other text visualizations [12], Wordle

stands out for its compact and aesthetic layout by placing small words in the space between big words or even in the space within a big word. In a few years since the introduction of the Wordle technique, wordles have proliferated in various contexts such as newspapers, education, presentations, and visual analysis [8, 13]. Wordle's popularity has also spawned tag cloud services and tools<sup>2,3</sup> based on the Wordle technique.

However, the initial Wordle technique provides people with limited control in the wordle creation process. For example, it provides a fixed set of layout and styles, and people just choose a favorite one among them; people cannot fine-tune the appearance of a wordle. Such limited control may keep people from creating the wordle in a way they like. To tackle this issue, Koh et al. introduced ManiWordle, the first interactive wordle authoring tool that supports direct manipulation on a word [5]. Designed and developed for a desktop environment, ManiWordle allows people to move and rotate a word with a mouse. Their user study shows that ManiWordle provides higher user satisfaction, and most participants liked ManiWordle more than Wordle.

<sup>1</sup> <http://www.wordle.net>

<sup>2</sup> Tagul - Gorgeous tag clouds. <http://tagul.com>

<sup>3</sup> Tagxedo - Word Cloud with Styles. <http://www.tagxedo.com>

	ManiWordle [5]	WordlePlus
Moving a word	Drag (mouse)	Drag (touch)
Rotating a word	Drag a handle (mouse)	Rotate (touch)
Resizing a word	Not supported	Pinch (touch)
Merging, concatenating, grouping two words	Not supported	Two-handed interaction (touch)
Adding a word	Not supported	Writing a word (pen)
Removing a word	Context menu (mouse)	Striking out a word (pen)
Selecting a word	Click (mouse)	Drawing a circle (pen)
Moving, rotating, resizing a wordle	Not supported	Drag, rotate, pinch on canvas (touch)
Animation	Not supported	Supported

**Table 1: Comparison of ManiWordle [5] and WordlePlus on their interaction and features. Instead of mouse-based interaction, WordlePlus uses pen and touch interaction to provide natural interaction. Also, WordlePlus supports the authoring of a wordle with animated creation and emphasis.**

Inspired by these encouraging results, we further advance the direct manipulation approach in WordlePlus (Figure 1 and Table 1) for pen- and touch-enabled tablets, enabling people to create custom, dynamic wordles. With WordlePlus, we explore new possibilities of the Wordle technique, strengthening the preferences for the original Wordle such as emotional impact, attention-keeping visuals, and being organic/nonlinear [13]. WordlePlus strives to provide more fluid wordle creation experiences through *natural interaction* and to enable people to create more dynamic and engaging wordles with *animation*.

## Related Work

### *Natural Interaction for Information Visualization*

With the rapid advancement in input, interaction, and display technology, Lee et al. advocate more efforts on applying a new paradigm called post-WIMP interfaces or Natural User Interfaces (NUIs) for information visualization [6]. Several researchers have been exploring ways to go beyond the traditional desktop environment. Through a Wizard of Oz study, Walny et al. show how pen and touch interaction can replace the use of the WIMP interface paradigm for information visualization [14]. Lee et al. develop a working system that supports more fluid pen and touch interaction based on the lessons learned from

Walny et al.'s study, investigating the benefits and challenges of combining pen and touch interaction. [7]

More specifically, with the recent explosion of multitouch-enabled tablet devices, researchers explore how to expand and improve previous mouse-based interactions for tablets. For example, TouchWave introduces a set of multi-touch interactions to alleviate the main shortcomings of stacked graphs [2]. Kinetica lowers the barrier of multivariate data exploration by exploiting multi-touch interactions and physics-based affordances [10]. Sadana and Stasko explore the design space of multi-touch interactions for visualizations by designing and developing touch interactions for an interactive scatterplot [11]. Inspired by these projects that leverage pen and touch interaction, we revamp interactions for wordle creation on tablets with kinetic manipulation and integrated interaction.

### *Animation for Information Visualization*

Even though wordles are aesthetically pleasing, they are static; wordles are usually captured and saved as static images, or printed out on a paper. Several visualizations (e.g., Gapminder<sup>4</sup>) with animations have proven popular and engaging. Robertson et al. find people feel fun and exciting about animation in trend visualization [9]. Also, Gershon and Page advocate the use of animation for storytelling in information visualization [4]. We believe

<sup>4</sup> <http://www.gapminder.org>

animation can improve Wordle to bring more emotional impact and be attention-keeping, which are the main strengths of Wordle compared to tag clouds [13]. People who notice the possibility of wordle animation share their tricks to animate a wordle, for example, by using a slideshow (<https://www.screenr.com/BOD>). However, these tricks are ad hoc, tedious, and incomplete. We design and develop a user interface and interaction (Figure 2) that enable people to easily add animations to a wordle. In addition to make the resulting wordle more dynamic, we believe wordle animation facilitates people to further engage in the wordle authoring.

**WordlePlus**

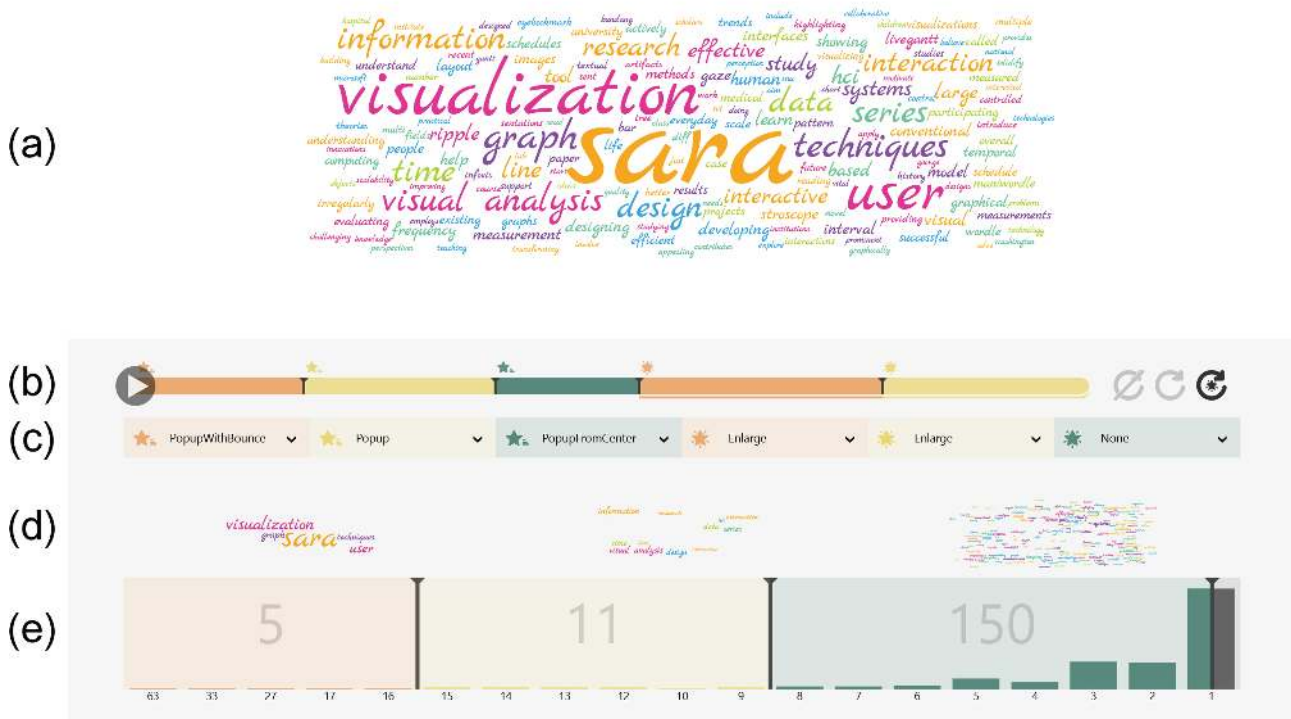
*Design Rationale*

WordlePlus is designed to help people create an aesthetic and dynamic wordle leveraging natural interaction

and animation. In this section, we describe our design rationale.

**1. Leverage Kinetic Manipulation on Tablets**

To design simple and natural interaction, we employ kinetic manipulation [2], enabling the creation of the layout through touching, dragging, and rotating virtual objects. We treat words in a wordle as objects on a table. People can move, rotate, and resize a word using their fingers. When two words collide as a result of the kinetic manipulation, we initially simulated movements of the words based on a physics model. However, it often makes words misaligned and scattered. For example, to avoid a rotation while moving a word, people have to drag the word at its exact center (which is nearly impossible); and to avoid inertia, they have to fully stop a finger movement before lifting it (which is not natural). To help people create an aesthetic and compact layout, we thus decided to break from a physics



**Figure 2: The user interface for animation configuration. (a)** A preview of wordle layout and animation; people can interact with the wordle within this preview area. **(b)** People can see how animation progresses. **(c)** People can specify two types of animation—creation and emphasis—for each group; orange and yellow groups have both animations, while green group has only creation animation. **(d)** A preview of each group. **(e)** The word frequency histogram shows the distribution of word frequencies. People can adjust the frequency range of a group and filter out low-frequency words by dragging separators between groups.

model, relocating the smaller word to the nearest available position when two words collide.

## 2. Support More Flexible Wordle Creation

Although Wordle was initially invented as a text visualization tool, we observe many uses of Wordle that deviate from formal data analysis. For example, in the Wordle's FAQ page (<http://www.wordle.net/faq>), people share their own wordle tricks to manipulate the font size by tweaking the input text, which breaks the fundamental size-encoding scheme of the Wordle technique. Furthermore, according to Viégas et al. [13], people use wordles for casual purposes, and a large portion of people tend to misunderstand the meaning of the size of a word in wordles. People seem to be rather interested in Wordle's visual appeal and aesthetic layout, so we decided to give full control to people, allowing them to break Wordle's size encoding principle. People can not only resize a word but also add a new word with a user-determined size and delete a word. While designing these new features, we bear natural interaction in mind. For example, people can easily add the word with a desired size by simply writing a word on the canvas.

## 3. Support Two-Word Manipulation

One of the limitations of previous wordle tools (designed for the traditional desktop setup with mouse and keyboard) is that they do not elegantly handle two-word phrases or two words with the same root. For example, the Wordle technique now lets people join words together by placing the tilde character (~) between two words in the input text [13]. However, this requires to make changes in

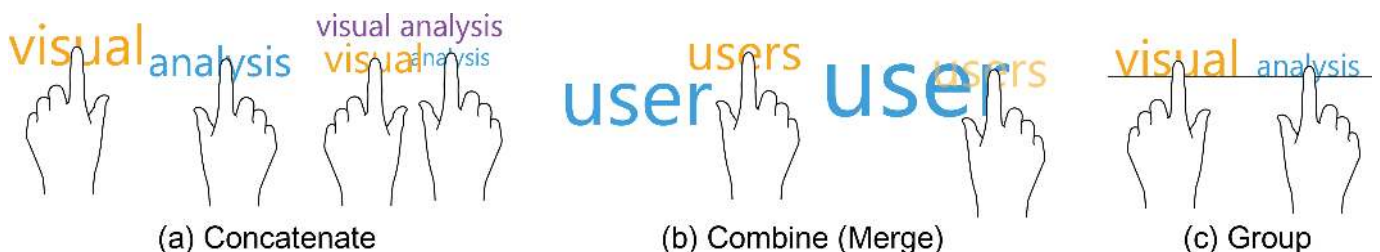
the input text and it is tedious to insert the tilde character between the words of the target phrases.

We initially considered several design alternatives such as Wordle's method (putting the tilde character between two words in the input text) or providing a dedicated widget. We decided not to use them because they introduce extra buttons or modes. Instead, inspired by Sketch Insight's two-handed interaction for charts [7] and the integrated interaction concept [2, 14], we chose to leverage two-handed interaction for two-word manipulations, and integrated them within the visualization space, eliminating the need of additional interfaces for two-word manipulation.

WordlePlus supports three types of two-word manipulation: concatenation, grouping, and combining (Figure 3). Concatenation can be performed by overlapping two words with one finger dragging each word (Figure 3a), whereas grouping can be performed by aligning two words horizontally or vertically again with one finger dragging each word (Figure 3c). For grouped words, split can be done by moving away two words from each other with one finger dragging each word. Combining (or merging) can be performed by dragging and dropping one word onto the other (Figure 3b).

## 4. Support Engaging Wordle Consumption on the Web through Animated Creation and Emphasis

To make the wordle consumption experience more engaging and exciting, we enable wordle authors to add animation to wordles. To support a more flexible animation, we decide to provide a two-phase animation: for creation and for emphasis. Animation for the creation phase



**Figure 3: WordlePlus provides two-word manipulation using natural interaction. (a) Concatenate.** Overlapping two words with one finger for each word creates a concatenated phrase. The original two words shrink as only the standalone occurrences of each word count. **(b) Combining.** Overlapping a word “users” onto another word “user” combines two words. The word “users” becomes bigger as the frequency of the word increases to the sum of the two words’ frequencies. People can preview the increased size of the word “user” while holding their finger on the word “users.” Once the finger released, the word “users” disappears (now shown). **(c) Grouping.** Aligning two words links the words as a group. Grouped words move/rotate together.

determines how words first appear in the wordle, such as flying in from the outside of the screen. On the other hand, animation for the emphasis phase provides additional highlights after all words in a wordle appear, such as enlarging a word for a while.

To enable people to easily share their animating wordles, we decided to use standard web-based technologies—HTML5 and JavaScript—without relying on extra plugins. This allows people to not only easily embed a wordle into websites but also deploy animating wordles on various platforms including mobile phones.

Although integrated interaction has advantages, not every interaction can be integrated with the visualization space. Configuring animation is done through a standard user interface that can be invoked through the Bezel Swipe gesture from the bottom edge of the screen. In addition, it is challenging to design a set of meaningful interactions for specific purposes that people can easily learn and remember. For example, we do not have a standard gesture for abstract commands such as re-layout and changing the background. Thus, for actions that cannot be supported through integrated interaction, we employ on-demand radial menus, one for each word and another for the wordle itself, as alternatives.

### *Interacting with WordlePlus*

We describe WordlePlus' interactions by following a simple scenario: Sara creates a dynamic wordle as a visual summary of her research using the titles and abstracts from her papers and shares the resulting wordle on the web.

#### **1. Wordle Initialization**

Sara chooses a text file that contains the titles and abstracts from her papers using a standard file dialog. After loading the text file, WordlePlus shows an initial layout. She realizes her wordle contains too many words and therefore decides to filter out some tiny words. After opening the control panel by performing the Bezel Swipe gesture from the bottom, she adjusts the size of the gray group (Figure 2e) to drop many low-frequency words. As discarded words disappear from the wordle, the wordle becomes less crowded.

She now wants to look around for possible design alternatives for her wordle in terms of layout and styles (background, font, and color scheme). Sara touches and holds her finger on the screen to invoke the wordle menu. Then, she taps on the randomization button in wordle menu until she finds a compelling start. To tweak the color scheme of the wordle, she uses the color palette menu item. To choose the font she likes, she touches the font menu item.

#### **2. Two-Word Manipulation**

While reviewing the layout, she realizes that an important phrase (“visual analysis”) is separated as two individual words (“visual” and “analysis”). To combine them into a phrase, Sara drags the two words toward each other. Once the two words overlap, the phrase “visual analysis” pops up, and the two words shrink to represent their individual occurrences. When she lifts her fingers, WordlePlus adjusts the layout accordingly to accommodate the new phrase.

Sara also notices that “user” and “users” appear independently. She drags “users” and drops it onto “user” to merge them into one-word “user.” The word “user” gets bigger as the frequency of the word increases to the sum of the two words' frequencies.

She notices that two related words, “information” and “visualization,” are separated. To avoid the separation during the further re-layout, Sara decides to group them together. She drags the two words toward each other. Once the two words are close and aligned, an alignment line appears to indicate that the two words can be linked as a group. Note that the size of each word does not change because the grouping is used only for layout purposes (i.e., placing two words together). Grouped words move and rotate together.

#### **3. Pen Interaction**

Sara wants to place her name at the center of the layout. She writes her name on a blank area with a digital pen. WordlePlus suggests several potential candidates after recognizing her handwriting. Sara taps on a correct candidate, “Sara.” Then, her handwriting is replaced with the word “Sara.” The size of the word is determined based on the size of her handwriting. She makes the word bigger



**Figure 4: Pen interaction. (a) People can strike through a word to remove it; after the word disappears, words that are located at the boundary of the wordle move to fill the blank area. (b) People can draw a circle that encompasses the word to select a word too small to be selected with a touch; upon selection, a handle for manipulation appears.**

by using a pinch gesture. She drags the word to the center of the wordle.

Sara spots irrelevant words such as “abstract” and “keyword.” She removes them by drawing a strikethrough on the words using the digital pen (Figure 4a); once she lifts her pen, the word below the strikethrough disappears, and small words on the boundary of the wordle fly in to fill the blank area resulting from the removal.

Sara wants to increase the size of the word “design.” However, the size of “design” is too small to manipulate the word with her fingers. So, she draws a circle encompassing the word to bring a handle for the word, which is a proxy for manipulation on the word. She increases and rotates the handle to manipulate the tiny word (Figure 4b).

#### 4. Radial Menu Interaction

After Sara obtains satisfactory layout and styles, she fine-tunes the details of the wordle. First, she wants to change the colors of some important words to emphasize them further. After she touches and holds on a word, available colors appear in a circle at the center of the word. She taps on the color she likes. Then, she taps on the re-layout button to relocate untouched but scattered words resulting from the collision with words she manipulated. Finally, she adjusts the position and size of the entire wordle to make it fit into the screen by dragging and resizing the canvas.

#### 5. Adding Animation

Now, Sara wants to add animations to the wordle. She opens the animation configuration panel (Figure 2) by performing the Bezel Swipe gesture. In the word frequency

histogram, showing the distribution of word frequencies in the text (Figure 2e), she adjusts the separators between groups to change the frequency range of each group. As Sara moves the separators, group previews above the histogram are updated to show a summary of words that belong to each group (Figure 2d).

Sara picks up animations for each group—*Popup with Bounce* creation and *Popup* emphasis for the high-frequency group, *Popup* creation and *Enlarge* emphasis for medium, and *Popup from Center* creation for low (Figure 2c), not emphasizing the low-frequency group. She also tunes a portion of each animation in the entire timespan by manipulating the corresponding bar on the timeline (Figure 2b). Then, she decides to repeat only emphasis animations by tapping on the rightmost button next to the animation play bar (Figure 2b). Lastly, she previews her animation by playing the whole animation and by moving the slider on the progress bar forward and backward as in a video player.

#### 6. Export

After Sara finalizes her wordle animations, she taps on the save button in the wordle menu. She then enters the name of her wordle using a standard file dialog. After saving is completed, she uploads the output HTML file to her website to make it accessible through the web.

#### Animation Configuration

This section describes our design process for wordle animation and rationales behind the design.

##### 1. Initial Design

We decided to provide a standard user interface for configuring animation because we do not have a sufficient number of logical pen and touch interactions that can cover the whole configuration process. For example, we do not have a standard gesture for setting an animation for a word or filtering out some words. The animation configuration panel is initially hidden and can be invoked through the Bezel Swipe gesture usually after people determined the layout and styles of a wordle.

Figure 5 shows our initial design for the animation configuration panel. Because configuring the animation for each word can be very tedious, we chose to adopt a group-based method for animation configuration. Words are separated into three groups according to their frequency; orange for the high frequency, yellow for medium, and green for low (Figure 2e and Figure 5c). We opted for three groups to strike a balance between flexibility in animation and user burden in group management. In addition to the three groups, we adopt one more group, gray, which represents filtered-out words. People can adjust the frequency ranges of the three groups and filter out low-frequency words using the gray group by dragging the separators between groups in the word frequency histogram (Figure 2e and Figure 5c). The color of a bar in the histogram indicates which group owns the words with the frequency of the bar.

To provide more flexibility in wordle animation, we determined to separate the animation into two phases: for creation and for emphasis. Animation for the creation phase—*Popup with Bounce*, *Popup from Center*, *Popup*, *Fly In*, *Float In*, *Fade In*, and *None*—determines how words first appear in the wordle. On the other hand, animation for

the emphasis phase—*Enlarge*, *Blink*, *Fade Out Other Words*, and *None*—provides additional highlights after all words in a wordle appear. People can choose animation for each group and phase using six animation selectors in the animation configuration panel (Figure 2c and Figure 5b).

## 2. Refining the Initial Design

Based on the informal feedback we gathered during the iterative design process, we improved the initial design as follows. First, we arranged six animation selectors (Figure 5b and Figure 2c) in a single line so that the order of the selectors is aligned with the order of animation in the timeline. To improve the affordance of draggable controls (i.e., group separators and animation phase separators), we added funnel-shaped markers as signifiers (Figure 5a and Figure 2b). Also, we included group previews to show a summary of words in each group (Figure 2d).

In addition, we incorporated repeated animation. We decided to support three default repetition options: 1) no repeat, 2) repeat of creation and emphasis animation, and 3) repeat of only emphasis animation. We opted out of repeating only creation animation because it makes a wordle incomplete (i.e., only some of the words are shown) most of the time during the animation. However, people can still achieve this by disabling all emphasis animations (i.e., selecting *None* for emphasis animations) and choosing the option of repeating both creation and emphasis animations.

People can select one repeat option using radio buttons next to the animation play bar (Figure 2b). Repeated animations are represented with an overlapped bar on the play bar (Figure 2b, orange and yellow bars on the right).

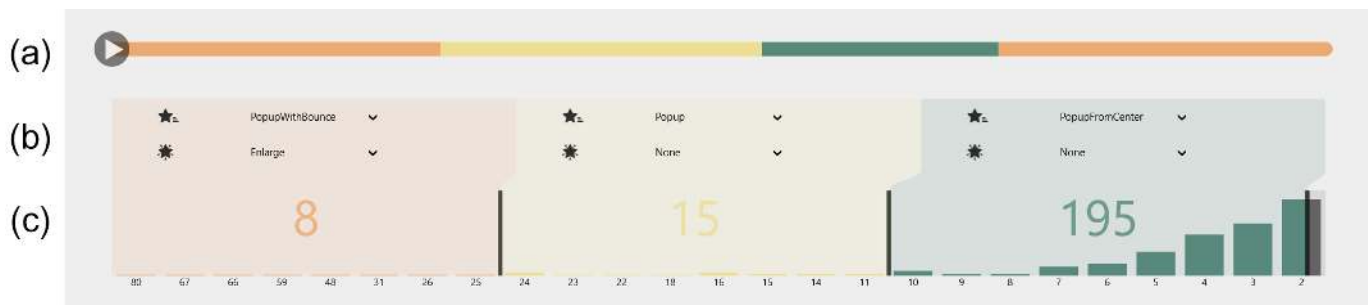


Figure 5: An initial design of the animation configuration panel; six animation selectors were arranged in two rows by group and the signifiers for animation phase separators and group separators were not clear. The final, improved design is shown in Figure 2.

### ***Accommodating Layout Changes***

One of the major differences between ManiWordle [5] and WordlePlus is that WordlePlus provides full control of words to people, including the ability to resize or delete a word. When people delete a word, an empty space can arise in the middle of a wordle's layout and thus hurt its compactness. As a remedy, ManiWordle [5] generates a new layout when people remove a word. However, because such method can be destructive (the layout changes drastically), WordlePlus adopts a method for a more stable layout—filling the empty space with words from the boundary of a wordle (Figure 4a).

When an empty space is introduced, WordlePlus tries to fill the empty space; WordlePlus repeatedly places some other word within the space until no word fits into the empty space. Because WordlePlus considers the word that is farthest from the empty space first, it is likely that words at the boundary of the wordle are used to fill the empty space. When people increased the size of a word, the adjacent words that collided with the enlarged word are pushed out to the nearest positions that the words fit into.

Our simple approach does not always work out well. Thus, alternative methods [3, 15] can be used to provide more stable and meaningful layouts.

### ***Implementation Details***

WordlePlus is developed in C# on Microsoft Windows Runtime and handles both pen and touch input; it runs on any pen- and touch-enabled Windows device such as a Microsoft Surface Pro 3. Handwriting recognition is done by APIs that Windows Runtime offers.

To export a wordle using only standard web-based technologies, WordlePlus first converts a wordle into a JSON format that contains information about the wordle, such as layout (x-y position and rotation of words), styles (color and font), and animation (timing and type). The output HTML file also includes JavaScript codes that reconstruct the wordle and its animation using Scalable Vector Graphics (SVG) elements based on d3.js<sup>5</sup>. So as not to introduce any extra file, WordlePlus converts the

background image into an inline image and ships the font of the wordle through Google Font API<sup>6</sup>.

People can embed their wordle in a web page by copying the output HTML codes to the web page and inserting an *svg* element with the *id* attribute set to “wordle” to where they want to place the wordle. By default, the wordle is automatically resized according to the size of the container element. However, people can specify the size of the wordle by setting the *width* and *height* attributes of the *svg* element to fit their wordles into the web page.

### **Discussion and Future Work**

We designed and developed WordlePlus to expand the use of Wordle, a popular visualization technique, by devising natural user interaction and animation. In this section, we discuss interesting challenges and directions for future work.

#### ***Learnability vs. Discoverability***

Treating a word as an object on a table helps people discover essential interactions for customizing a wordle, such as moving and rotating a word. In addition, people are likely to discover the interactions that became a de facto standard (e.g., touch-and-hold on an object to invoke a context menu). On the other hand, our new two-word interactions may not be easily discoverable since we do not use such interactions with real objects in our everyday life and they are not commonly used in a multi-touch environment yet. However, we believe that they are easy to learn and remember because they are based on logical rules and provided with meaningful feedback. More work is needed to understand the learnability of these new interactions that do not have any direct correspondence with real-world actions. Also, it would be helpful to evaluate the usability and effectiveness of our design in the future either by conducting a controlled lab study or by releasing the tool to a wide audience.

#### ***Collaborative Wordle Creation***

We can further extend WordlePlus targeting other environments such as interactive tabletops. One advantage

---

<sup>5</sup> <http://d3js.org>

<sup>6</sup> <http://www.google.com/fonts>



of interactive tabletops compared to conventional desktops and tablets is the potential of supporting collaboration. The current WordlePlus design partially supports collaborative scenarios. For example, it can handle multiple interactions performed on separate words simultaneously. However, to support collaborative wordle creation more effectively, we need to address some issues. For example, two-word manipulation can be a problem because current implementation cannot recognize whether two fingers are from the same person or from two different people. The orientation of radial menus and animation configuration panel is another problem because people usually stand around a tabletop, and therefore, we need to figure out a “right” orientation for each person.

### **Interaction Outside of the Screen**

With the current design, all interactions happen within the screen of a tablet. However, we can think of natural interactions that occur outside of the screen. For example, shaking a tablet can be thought of as an interaction for randomizing a wordle if we regard the tablet as a container and a word as an object in the container. Similarly, by standing a tablet upright, people can obtain a new type of wordle layout where bigger words are stacked from the bottom of the screen, assuming that bigger words are heavier. As shown in both scenarios, future work may include exploiting the physical metaphor of a tablet to introduce novel interactions.

### **Interactive Wordle**

WordlePlus made a first step going beyond a static wordle, employing animation with the standard web-based technologies. We now can envision an interactive wordle, where the wordle audience interacts with a wordle to access additional information. For example, WordlePlus can be extended to highlight related words (e.g., words co-occurred in a same sentence) when people move the mouse cursor over a word. WordlePlus can enable people to link a word to a website, which can be opened when the word is selected. In addition, as can be done with the standard tag clouds [1], WordlePlus can be used as a way to specify a search keyword.

## **References**

1. 5 Ways You Can Search The Web Using Tag Clouds, <http://www.makeuseof.com/tag/5-ways-search-web-tag-clouds>.
2. Baur, D., Lee, B., Carpendale, S. TouchWave: Kinetic multi-touch manipulation for hierarchical stacked graphs. *Proc. ITS*, 2012, 255–264.
3. Cui, W., Wu, Y., Liu, S., Wei, F., Zhou, M.X., Qu, H. Context preserving dynamic word cloud visualization. *Proc. PacificVis*, 2010, 121-128.
4. Gershon, N. Page, W. What storytelling can do for information visualization. *CACM* 44, 8 (2001), 31–37, 2001.
5. Koh, K., Lee, B., Kim, B., Seo, J. ManiWordle: Providing flexible control over wordle. *IEEE TVCG (Proc. InfoVis)* 16, 6 (2010), 1190–1197.
6. Lee, B., Isenberg, P., Riche, N.H., Carpendale, S. Beyond mouse and keyboard: Expanding design considerations for information visualization interactions. *IEEE TVCG (Proc. InfoVis)* 18, 12 (2012), 2689–2698.
7. Lee, B., Smith, G., Riche, N.H., Karlson, A., Carpendale, S. SketchInsight: Natural data exploration on interactive whiteboards leveraging pen and touch interaction. *Proc. PacificVis*, 2015.
8. McNaught, C. Lam, P. Using wordle as a supplementary research tool. *Qualitative Report* 15, 3 (2010), 630–643.
9. Robertson, G., Fernandez, R., Fisher, D., Lee, B., Stasko, J. Effectiveness of animation in trend visualization. *IEEE TVCG (Proc. InfoVis)* 14, 6 (2008), 1325–1332.
10. Rzeszutarski, J.M. Kittur, A. Kinetica: Naturalistic multi-touch data visualization. *Proc. ACM CHI*, 2014, 897–906.
11. Sadana, R. Stasko, J. Designing and implementing an interactive scatterplot visualization for a tablet computer. *Proc. AVI*, 2010, 265–272.
12. Viégas, F.B. Wattenberg, M. Tag clouds and the case for vernacular visualization. *Interactions* 15, 4 (2008), 49–52.
13. Viégas, F.B., Wattenberg, M., Feinberg, J. Participatory visualization with wordle. *IEEE TVCG (Proc. InfoVis)* 15, 6 (2009), 1137–1144.
14. Walny, J., Lee, B., Johns, P., Riche, N.H., Carpendale, S. Understanding pen and touch interaction for data exploration on interactive whiteboards. *IEEE TVCG (Proc. InfoVis)* 18, 12 (2012), 2779–2788.
15. Wu, Y., Provan, T., Wei, F., Liu, S., Ma, K.-L. Semantic-preserving word clouds by seam carving. *Computer Graphics Forum (Proc. EuroVis)*, 30, 3 (2011), 741-750.

**Jaemin Jo** is a Ph.D. student in the Department of Computer Science and Engineering, Seoul National

University, Seoul, Korea. His research interests include human-computer interaction and information visualization. He received the B.S. degree in computer science and engineering from Seoul National University, Seoul, Korea in 2014.

**Bongshin Lee** is a researcher in the neXus group at Microsoft Research. Her research explores innovative ways for people to create information visualizations, interact with their data, and share data-driven stories

visually. She received her Ph.D. in computer science from the University of Maryland at College Park in 2006.

**Jinwook Seo** is an Associate Professor in the Department of Computer Science and Engineering, Seoul National University, where he is also the Director of the Human-Computer Interaction Laboratory. His research interests include HCI, information visualization, and biomedical informatics. He received his Ph.D. in computer science from the University of Maryland at College Park in 2005.