GEM-NI+: Leveraging Difference Visualization and Multiple Displays for Supporting Multiple Complex Generative Design Alternatives

Loutfouz Zaman
University of Ontario Institute of Technology
Oshawa, ON L1H 7K4 Canada
loutfouz.zaman@uoit.ca

Christian Neugebauer
University of Applied Sciences Bonn-Rhein-Sieg
Bonn, Germany
christian@neugemail.de

Wolfgang Stuerzlinger
Simon Fraser University
Surrey, BC V3T 0A3
w.s@sfu.ca

Robert Woodbury
Simon Fraser University
Surrey, BC V3T 0A3
robw@sfu.ca

Abstract
In the conceptual design phase, designers routinely generate dozens of alternatives based on a single idea. This is especially relevant in generative design where an algorithm can generate a large number of viable design options. While solutions for creating and managing a small number of simple alternatives have been proposed, practical applications of these solutions are limited. As a result, we present *GEM-NI+*, an extension to the original *GEM-NI* system for creating and managing alternatives in generative design. *GEM-NI+* is designed to enable editing, managing and comparing up to 24 alternatives simultaneously using a multi-monitor setup. *GEM-NI+* also features a new “jamming spaces” technique for assigning individual monitors into different visualization states, which makes organization of a large workspace easier. Finally, *GEM-NI+* enables comparison of complex alternatives using recursive group node difference visualization.

CHI'18 Extended Abstracts, April 21–26, 2018, Montreal, QC, Canada

ACM ISBN 978-1-4503-5621-3/18/04.
https://doi.org/10.1145/3170427.3188593

Author Keywords
Alternatives, Dataflow Programming, Generative Design, Multiple Displays, Difference Visualization

ACM Classification Keywords
H.5.2 User Interfaces: Graphical user interfaces (GUI), I.3.4 [Graphics Utilities] – graphics editors

Background

The development of a design is conceptually a process where many threads of possibilities are developed in parallel. These concepts are then abandoned or re-combined until a satisfactory scheme emerges out of the exercise. Often, this exploration is directed by the outcomes of previous explorations. Thus, the search for *alternatives* and the exploration of the design space have very important roles in the design process.

Generative design is a modern design technology in which a set of rules or an algorithm generates the output, such as, e.g., 2D vector graphics. Generative systems often use a data-flow program as the underlying generative model to ensure that the generated output matches the goals, as specified as part of the model. This allows to explore a much larger number of viable design options compared to what is achievable with manual operations. However, how users manage and compare alternatives in such a large space of design has not been investigated in detail.

Many studies have investigated the effectiveness of large or multiple monitors in comparison to smaller or single screens. Based on the results of one particularly notable study, Grudin [7] emphasized the need to partition our digital world. Ball and North [2] analyzed usage of a large 3×3 tiled display in a longitudinal study and identified a decrease in cognitive load due to the possibility of glancing at secondary information and the reduced need for navigation. Experienced users tended to dedicate certain regions of the screen for particular applications, such as e-mail, and then relied on spatial memory. Andrews et al. [1] examined sense making on multi-monitor systems. With novices, they found a number of key behavioral differences for multi-monitors. Professional analysts used the additional space both as a form of rapid access external memory and as an added semantic layer where meaning was encoded in the spatial relationships between data, documents, display, and analyst.

Bi et al. [4] investigated how interior bezels on tiled-monitor large displays affect user performance and found that tiled-monitor large displays are suitable for visual search tasks. However, if high accuracy is required, objects should not be placed across bezels. Bi et al. [6] also compared a very large display (4.88m×1.83m) with single and dual monitors in a longitudinal diary study. They found a strong preference for the large display. A subset of participants reported mentally partitioning the screen real estate into focal and peripheral regions.
Bi et al. [5] designed a set of interaction techniques that provide greater flexibility in managing multiple windows. In their *Spread* technique a primary document is placed at the center and surrounded by supporting ones in a tiled layout. Sandstrom et al. [8] presented the *hyperwall*, a form of multi-tiled visualization, which uses coordinated visualizations for interactive exploration of multidimensional data and simulations. Beaudouin-Lafon et al. [3] presented a multi-surface interaction system for large datasets. It enables multiple users to easily and seamlessly create, share and manipulate digital content.

In our work, we use a tiled user interface to present many alternatives simultaneously and permit designation of particular monitors for specific functions. Our space redistribution feature generalizes the *Spread* method of Bi et al. [5] to tiled display arrangements. The extension of the *MACE* interface [9] for multi-tile visualization is a form of enhanced juxtaposition for the purpose of comparing multiple alternatives.

Difference visualization techniques for generative design alternatives created using on average 10 nodes and connectors have been proposed [9]. However, to the best of our knowledge, no effective difference visualizations are currently available for networks substantially larger and more complex.

GEM-NI+

To make alternatives exploration in generative design more practical by accounting for many complex alternative designs, we present *GEM-NI+*, an extension to the original *GEM-NI* [9, 10] which enable the designer to:

- Compare large and complex alternatives using recursive group node difference visualization;
- Edit, manage and compare up to 24 alternatives simultaneously using a multi-monitor setup;
- Facilitate organization of a large workspace using a new "jamming spaces" technique for assigning individual monitors into different visualization states.

Group Node Difference Visualization

To enable difference visualization between alternatives with large and complex networks, we implemented a technique to visualize differences between group nodes. Group nodes incorporate networks which in turn can also incorporate networks and so on, making it possible to organize networks with large number of nodes using only a few nodes. Our technique supports visualization of differences between recursive/nested variations of these nodes as well. Our technique works with both subtractive and additive encodings [9]. The example below illustrated in Figures 1-4 demonstrates a use case where subtractive encoding was used for visualizing differences between three alternatives at three levels of grouping.

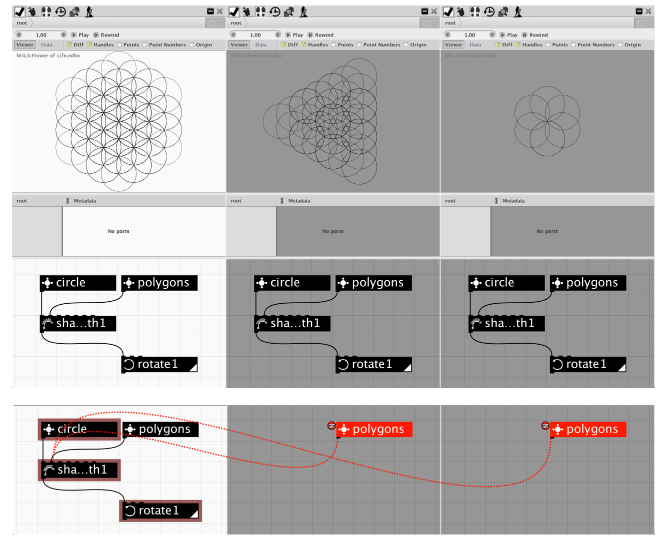

Figure 1. Three design alternatives which differ in the group POLYGONS node at group level 1.

The top part of Figure 1 shows the status of the workspace with difference visualization turned off. The bottom part shows a difference visualization highlighting in red the node POLYGONS in the network view in the middle and right alternatives. This indicates that there is a difference between these nodes relative to the reference node of the alternative on the left. However, on this level, the difference is not revealed. Entering POLYGONS presents the view in Figure 3. All three views are now displaying the contents of POLYGONS in each alternative. The top part shows contents with difference visualizations turned off. The bottom part shows a difference visualization highlighting the nodes POLYGON1 and POLYGON2_3 in red.

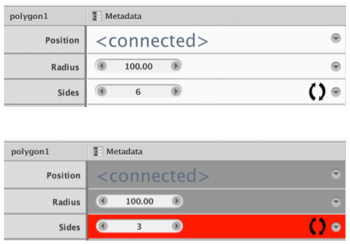

Figure 2. Difference visualization at level 2 highlights a change in “Sides”. The top view corresponds to the left alternative, the bottom – to the middle alternative.

POLYGON1 appears in all three alternatives and is also selected, which enables node-focused difference visualization on it [9]. This highlights the “Sides” parameter emphasizing that the value of 3 is different from the reference value of 6. See the zoomed parameter views in Figure 2. The “Sides” parameter of POLYGON1 in the right alternative also has the same value of 3 in the middle alternative (not shown). POLYGON2_3 is the last network not in this alternative. Entering it presents the view in Figure 4.

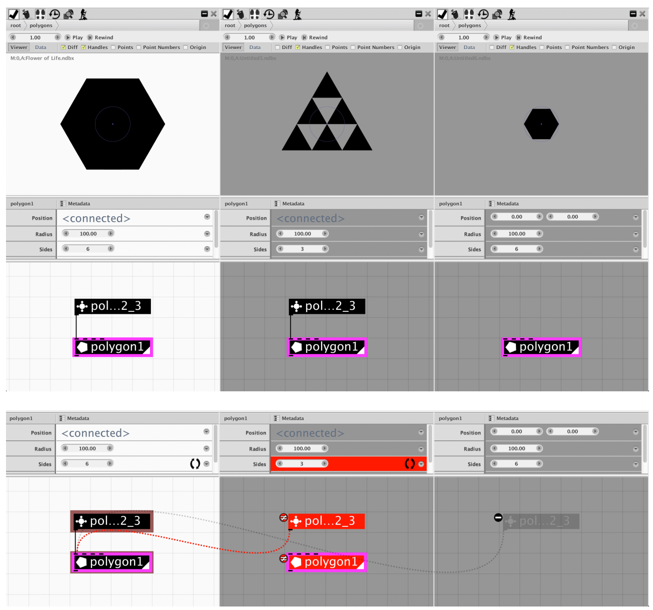

Figure 3. Difference visualization at level 2 inside POLYGONS node.

Here, the right alternative is completely disabled because the node POLYGON2_3 does not exist there. This is indicated by highlighting the whole alternative in red.

Note that the alternative is highlighted in both the regular mode (shown on top) and the difference visualization mode (shown at the bottom).

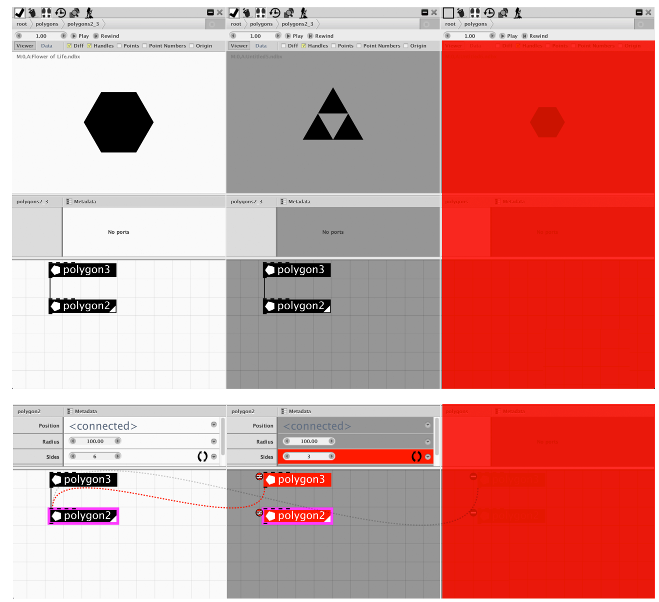

Figure 4. Difference visualization at level 3 inside POLYGON2_3 node. The right panel is disabled, because POLYGON2_3 does not exist in the network.

Managing a Large Number of Alternatives using Multiple Displays

In the conceptual design phase, designers routinely generate dozens of alternatives. That amount of content is difficult to fit onto a single monitor, if all alternatives are still to be view- and editable. Consequently, we added multi-monitor support in *GEM-NI* for (currently) up to 2x3 monitors to help the designer keep the overview of all alternatives. The

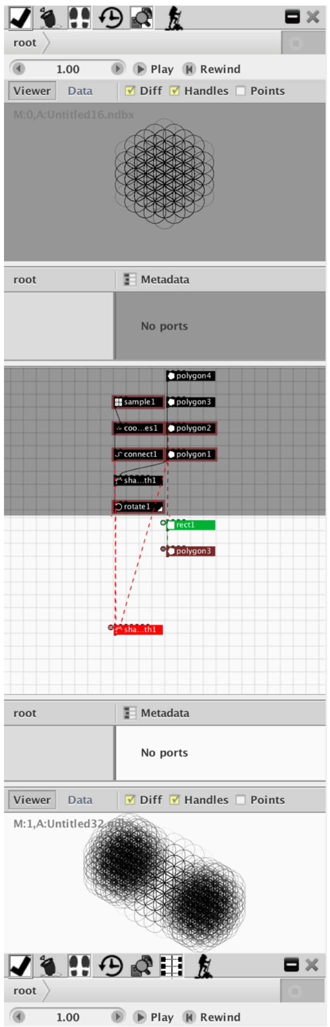

Figure 5. Two alternatives appearing in a 2×1 formation.

workspace is then re-arranged to spread all alternatives as evenly as possible according to the newly chosen monitor arrangement. Within each monitor, horizontal space is evenly redistributed depending on the number of alternatives on that monitor. This is a generalization of the Spread technique of Bi et al. [5] to tiled applications. For all monitor layouts with two rows, i.e., 2×1, 2×2 and 2×3, the model and network views are swapped on the bottom row. That way, the generative networks are always close together. This is especially beneficial for difference visualizations that use subtractive encoding [9] because connectors can cross multiple network views. Figure 5 shows a close up of two alternatives appearing side-by-side vertically as they would appear in a 2×1 monitor formation using subtractive encoding [9].

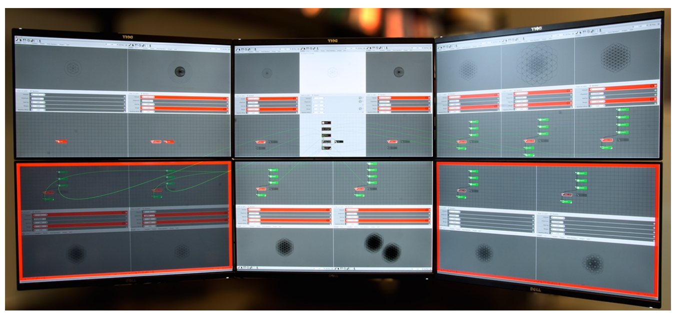

Figure 6. Our 2×3 multi-monitor setup displaying a total of 14 alternatives in a difference visualization relative to the top middle (reference) alternative. The bottom left monitor jammed into the idle state and the bottom right monitor jammed into the state where cross-alternative connectors are not displayed.

To test this new aspect of *GEM-NI*, we created a multi-monitor setup with six thin-bezel Dell U2414H monitors, in a 2×3 formation on an Ergotech multi-monitor stand with a total resolution of 5760×2160 pixels (Figure 6). To minimize the overall seams, we rotated the top row of monitors 180°. In Figure 6, 14 alternatives are being edited.

Jamming Spaces

Ball and North [2] identified that users tend to dedicate certain regions of a large display for certain applications and then rely on spatial memory. We believe this can be generalized to how screen space can be used for alternatives and consequently designed and implemented a new feature that supports the adaptation of the space to the current use case. Moreover, display space is an important resource in parallel exploration tasks. In our system we permit users to "jam spaces", i.e., monitors, into the following states: idle/non-idle; enable/disable display of cross-alternative connectors (for subtractive difference visualizations); and all combinations thereof [10].

This functionality directly affects all alternatives in a given monitor. When a monitor is jammed, a red frame is displayed around the border as a visual clue (Figure 6). Dragging an alternative into a "jammed" monitor affects the state of said alternative corresponding to the "jam" settings. In Figure 6 the two monitors at the left and right bottom respectively are both jammed. The one on the left is jammed in an idle state. The one on the right is jammed in a state where cross-alternative node connectors are not displayed.

Limitations

Our approach for multi-monitor support does not scale to a larger number of alternatives, say substantially more than 24, which means at least one monitor will display more than four alternatives. The reason for this is the physical limitations of the average user to see sufficient detail on today's desktop monitors. Adding more monitors is also problematic because objects appear smaller proportionally to their distance from the user due to perspective. Thus, a user can only keep track visually of all alternatives that appear in the center of the field of view. In order to accommodate hundreds of alternatives, a different interface will be necessary.

Conclusion and Future Work

We presented *GEM-NI+*, an extension to the original *GEM-NI* which enables editing, managing and comparing up to 24 alternatives simultaneously using a multi-monitor setup. We introduced a new "jamming spaces" technique for assigning individual monitors into different visualization states to facilitate organization of a large workspace. We also introduced a difference visualization technique for complex alternatives which uses recursive group node difference visualization. All these features have been integrated into the latest version of *GEM-NI* and are available for download[1].

In the future, we will evaluate the effectiveness of the multi-monitor environment and the new interaction techniques in a longitudinal user study with expert participants, who will be asked to create multiple complex generative design alternatives.

References

1. Andrews, C., Endert, A. and North, C. 2010. Space to Think: Large High-resolution Displays for Sensemaking. *CHI 2010* (New York: ACM), 55–64.
2. Ball, R. and North, C. 2005. Analysis of User Behavior on High-resolution Tiled Displays. *INTERACT '05* (Berlin, Heidelberg, 2005), 350–363.
3. Beaudouin-Lafon, M., Huot, S., Nancel, M., Mackay, W., Pietriga, E., Primet, R., Wagner, J., Chapuis, O., Pillias, C., Eagan, J.R. and others 2012. Multisurface interaction in the WILD room. *Computer*. 45, 4 (2012), 48–56.
4. Bi, X., Bae, S.-H. and Balakrishnan, R. 2010. Effects of Interior Bezels of Tiled-monitor Large Displays on Visual Search, Tunnel Steering, and Target Selection. *CHI 2010* (ACM), 65–74.
5. Bi, X., Bae, S.-H. and Balakrishnan, R. 2014. WallTop: Managing Overflowing Windows on a Large Display. *Human–Computer Interaction*. 29, 2 (2014), 153–203.
6. Bi, X. and Balakrishnan, R. 2009. Comparing Usage of a Large High-resolution Display to Single or Dual Desktop Displays for Daily Work. *CHI 2009* (New York: ACM), 1005–1014.
7. Grudin, J. 2001. Partitioning digital worlds: focal and peripheral awareness in multiple monitor use. *CHI 2001* (2001), 458–465.
8. Sandstrom, T.A., Henze, C. and Levit, C. 2003. The Hyperwall. *Proceedings of the Conference on Coordinated and Multiple Views In Exploratory Visualization* (Washington, DC, USA, 2003), 124–.
9. Zaman, L., Stuerzlinger, W. and Neugebauer, C. 2017. MACE: A New Interface for Comparing and Editing of Multiple Alternative Documents for Generative Design. *DocEng 2017* (ACM), 67–76.
10. Zaman, L., Stuerzlinger, W., Neugebauer, C., Woodbury, R., Elkhaldi, M., Shireen, N. and Terry, M. 2015. GEM-NI: A System for Creating and Managing Alternatives In Generative Design. *CHI 2015* (New York: ACM), 1201–1210.

[1] https://github.com/loutfouz/GEM-NI