A Mobile Interface for Hierarchical Information Visualization and Navigation

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ABSTRACT

There is a dramatic increase in the population who use mobile computing devices. Though the hardware becomes more powerful, effective support for information rendering on small screens very much lags behind. To display hierarchical information, researchers have proposed many algorithms for desktop screen visualization. Such algorithms are generally divided into *connection* and *enclosure*. *Connection* approach displays hierarchy with a clear structure but consume display area. *Enclosure* can maximally utilize the screen space but the layout is essentially implicit. This paper describes a new Radial Edgeless Tree (RELT) for visualizing hierarchical data on palmsized devices. The aim of RELT is to combine the advantages of connection and enclosure approaches. By recursively partitioning the display area, this technique maximizes the space usage. The structural clarity of layout can be reached by arranging location of non-overlapping regions. RELT can be adapted for visualizing structural information for various applications.

Keywords: *Mobile interface, Hierarchy visualization, Music classification, Navigation, Usability*

1 Introduction

This paper presents RELT for visualizing hierarchical information on mobile devices. Due to information explosion, people are no longer satisfied with the way information contents are retrieved. There is an urgent need for an innovative method that can show the essential relationships among information objects, that is, the organizational structure. Nowadays, visualization is fully fledged on desktops. A wide range of visual applications offer neat and easy understandable maps, forms, figures and diagrams to help people solve problem efficiently. The increasingly powerful graphic capabilities and processing speed have made visualization prevalent in many application domains, including business, medical sciences and so on. In fact, improved visualization methods and associated applications have changed the way that people handle large amounts of information.

Researchers have begun to design visualization methods for mobile devices. They found that it is clear that one cannot simply scale visualization methods designed for desktops to fit mobile devices. This is because of the essential technical limitations in downward scaling, as compared in Table 1.

Feature	**Mobile device**	**Desktop**
Screen Size	Small	Large
Colors	Few	Many
Input Devices	Tiny button Pen	Mouse Keyboard
Width/Height	Varied	Around 4/3
Connectivity	Slow	Fast

Table 1: Comparison between mobile devices and PCs

Many application domains use hierarchies to organize and retrieve information, or to represent organizational structures. Graphs may be transformed into hierarchies by some techniques [1]. Due to these features of hierarchical structures, visualizing hierarchical information becomes an emerging challenging research topic.

Hierarchy visualization approaches can be classified as *Explicit* vs. *Implicit* and *Horizontal* vs. *Radial* [3]. The more general classification of the previous hierarchy visualization approaches is Connections and Enclosure.

The ***Connection*** approach can be considered the *Explicit*. *Horizontal* and *Radial* are both connection-based. The general idea depicts every information object as a node and an edge linking two nodes together represents the relationship between two information objects. Recent research focuses on how to locate these nodes. Balloon view [4][5], radial view [4][9], and space-optimized tree visualization [11] are typical connection-based approaches. These approaches lead to layouts which match the human's cognitive recognition of hierarchical structure, so it is easy for users to catch the underlying information structure from the layout.

Enclosure is an implicit approach. This space partitioning method recursively divides the entire screen and evenly locates each node and its sub-hierarchies inside the region of its parents. The enclosure approach maximizes the usage of mobile screens. Its disadvantage is that the hierarchical structure is sometimes too implicit to understand. Treemap [2] is a typical example of this approach.

The methods introduced above are primarily developed for desktops and cannot be simply scaled to suit mobile devices. Based on the above discussion, mobile visualization limitations, especially for small screens, challenges the expressiveness, effectiveness and appropriateness of normal visualization methods. From a purely user understandable point of view, connection-based approaches work well. From a space efficiency point of view, enclosure economically utilizes the display area. Aiming at high usability and economic screen usage, we proposed the RELT approach.

The rest of this paper is organized as follows. Section 2 introduces the current research in hierarchy visualization on mobile devices, and then the RELT approach. Section 3 applies RELT on a mobile interface for visualizing music classification. A comparison to other existing mobile music visualization methods will be made. Section 4 compares the RELT music navigation with a typical cascading menu navigation approach. Finally Section 5 discusses the future work and conclusion.

2 Current Hierarchical Information Visualization Techniques vs. RELT

2.1 Current Status

Most current hierarchical information visualization methods derive from the ones for PCs. To enhance better usability, most of them choose to develop connection-based approaches with clear structure. Karstens *et al.* [3] contributed two points on the mobile hierarchy information visualization. One is to set up the criteria and requirements of mobile visualization method. Another is to propose a general procedure of designing a mobile visualization method based on an existent one for PCs.

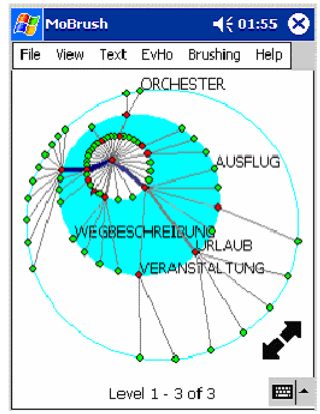

Figure 1: Visualization of hierarchical structures using Magic Eye View on a mobile device.

Figure 1 illustrates the layout using modified Magic Eye View [3] on a mobile simulator. This method can visualize one thousand nodes, ten times more than that by a traditional drawing method [8].

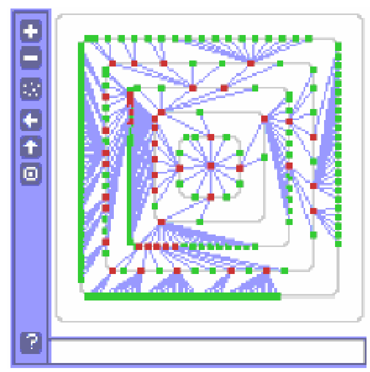

Figure 2: Visualization of 332 nodes using Rectangular View

As illustrated in Figure 2, Rectangular View [3] is also a successful hierarchy visualization method. This method is claimed to be able to handle hierarchy of 3389 nodes.

The two methods discussed above successfully deal with large hierarchical information with explicit interactive relations. They, however, they both fail to make economic screen usage. It is obvious that many parts of screen are still left unused.

2.2 Radial Edgeless Tree

The underlying limitations of existent approaches make it impossible to achieve both layout clarity and maximal usage of the display area by simply modifying desktop methods. RELT aims at combining the advantages of connection and enclosure approaches.

The name of RELT reveals this method's features. Hierarchical information is visualized in a radial layout. Instead of using space-consuming edges to explicitly make relationships, RELT uses adjacency and direction to represent relationships between nodes. RELT can be understood as "Seigniory Partition" problem guided by the following rules:

- The root of the hierarchy is the monarch who locates at the upper left corner. His domain is the entire display area.
- A seignior's rank is represented by a number in decreasing order of ranks.
- The higher rank that seignior is, the bigger space he owns.
- Monarch partitions the entire area for his seigniors. Each seignior has responsibility to partition his space for seigniors under him.
- Each seignior locates at the upper left position of his space.
- Seigniors are given seigniory based on their contributions. Seignior's weight is used to represent contribution and calculated by following rules (w_S is the weight of a seignior S):
  1. If *S* is a lowest ranked seignior, $w_S = 1$. (i.e. at the bottom level of the hierarchy).
  2. If S is not lowest ranked and has k affiliated seigniors $\{S_{a1}, S_{a2} \ldots S_{ak}\}$, then

$$w_S = 1 + \sum_{i=1}^{ak} w_i \qquad (1)$$

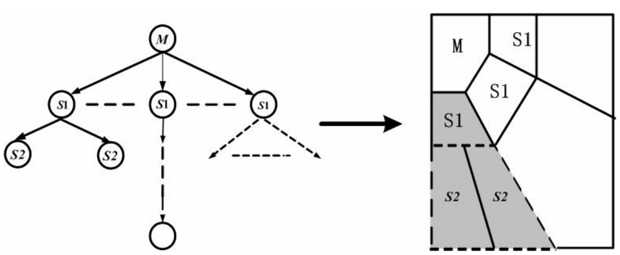

Figure 3: An example of seigniory distribution

By applying these rules, the emperor E partitions the whole domain (display area) for his seigniors S1, S2 and S3 (Figure 3). For example, the shaded area in Figure 3 is the territory given to S1. S1 will keep the upper trapeziform and again partition the trapeziform surround by dash line to his affiliated seigniors S11 and S12. Because S11 and S12 have the same weight by Equation (1), they have the same size seigniory.

The hierarchical information is displayed with a clear layout, as shown in Figure 4. For a seignior, its upper seignior is in the upper left direction, the seigniors under it are in the low right direction. The same ranked seigniors locate along the dashed curve. In addition, this method recursively divide the whole display area, so the screen is maximally utilized.

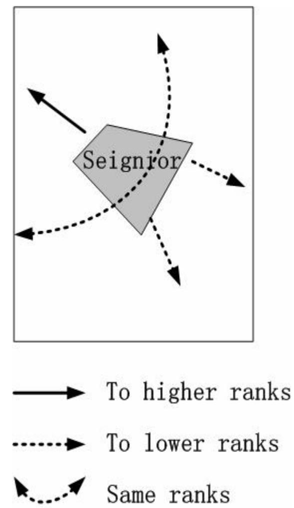

Figure 4: Layout arrangement of rankings (Solid arrow points to higher ranks; dashed arrows point to lower ranks; dashed curve arrows show the same ranks).

The algorithm is defined as follows:

procedure RELT (**matrix** *ad_matrix*)
begin
Para_Creator (*ad_matrix*)
// Calculate the necessary parameters for each node.
DFS (*ad_matrix*)
// Use Depth first search to traverse the tree
  if vertex v is new **then**
    Polygonal_Node (*v*)
    // Assign a region to v with rule L
    Partition_Area(*v*)
  // Divide the area depending on the weights of v's children
fi
end

Hierarchy information is stored in the adjacent matrix. **Para_Creator** initially calculates the necessary parameters of the hierarchy. Depth first search is employed to traverse the hierarchy. When a new vertex is met, a polygonal area is given to the new vertex by **Ploygonal_Node**. **Partition_Area** partitions the remaining area for the children.

3 Music Selection

This section discusses the application of the RELT approach to the music selection, a prevalent application of hierarchy visualization. Section 3.1 introduces the current music classification and selection methods and

Section 3.2 demonstrates how RELT is employed on an example music collection.

3.1 Existing Approaches

Multiformity of accessing mobile digital archives, the improving mobile storage techniques, effective Web services and enhanced mobile hardware are all making music widely accessible. This indeed marks a characteristic of the digital world. A digital music business report [6] claims that traditional CD sales are declining. The digital music business, however, is now experiencing an explosion. Four hundred and twenty million tracks were downloaded in 2005, up more than twenty times from 2003. Based on the survey and statistics, this seems to be just the beginning of the new music business.

When selecting from a large amount of songs, people find it hard to navigate in through the music archive. A method which can better organize music archives is urgently needed. Although all the aforementioned improvements have provided tremendous opportunities for wide music access, research on music classification navigation for mobile devices are still at its infancy.

We divide the current music classification and selection applications roughly into two types: *2D* and *3-D*.

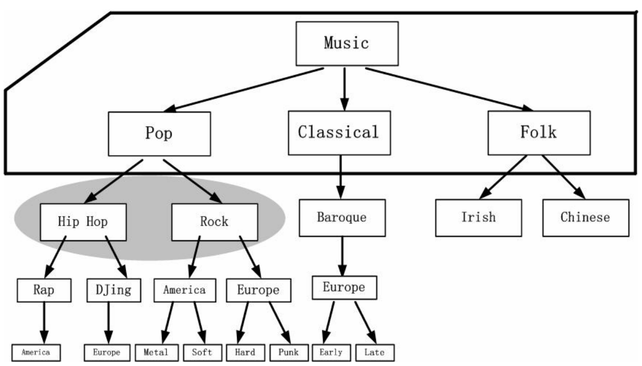

Figure 5: An example music archive represented as traditional tree

The 2D type is the most commonly used. Cascading menus across multiple screens is a typical 2D example. The navigation scheme is simple, such as artist → album → track. The user may define a preferred scheme on some devices, such as IPOD. This type of navigation scheme restricts the view at any instant of time to only all the children of a node that is selected. For example, many music archives classify music items based on their types, such as "Classical" and "Pop" shown in Figure 5. If menus are employed, the user can only see the music types "Hip Hop" and "Rock" when "Pop" is selected, as illustrated by the shaded ellipse in Figure 5. The global view is simply lost in such an arrangement. For example, the user cannot see what are under "Classical" and "Folk".

The 3D type is simply a simulated 3D view with realistic looking albums. Iphone, a recent product of Apple, utilizes the album's cover picture to represent each album. Album browsing on the mobile device is simulated just like searching for an album on a CD shelf, essentially linearly by moving between left and right while the item in the center is displayed fully (Figure 6). Although this simulation looks attractive, its linear structure makes it inefficient in searching. It could become an unpleasant experience if one has to scan through hundreds even thousands of albums to find one item.

Figure 6: Iphone linear 3D music organization

Researchers have also developed techniques for organizing music by extracting audio signal features according their similarity. Kness et al. [10] introduced a method to simulate a given collection of music as a virtual landscape. Music items are clustered based on their similarity. A 3D landscape is built based on the clustering. The more songs are similar in a particular music collection, the higher is in the corresponding region. When traveling through the terrain, the music corresponding to the user's virtual position will be heard. This is nice innovation to relate the music organization to a landscape. Music browsing can be vivid and lively. Because the landscape is constructed based on the similarity, it is difficult for the user to locate the exact location of an item. Although labels and icons will help users to search, traveling around the landscape is still needed to find a music piece.

3.2 Music Classification View on RELT

RELT contains hierarchical information whose structure is clear at one glance. Using cascading menus in a music archive, if the user travels along Music → Pop → Rock (at least two clicks), all the information that the user can retrieve is visualized as a polygonal area in Figure 5. The RELT screen in Figure 7 keeps the same structural information as in Figure 5. The user can understand the whole structure and relations at one glance (without a click). Further more, RELT efficiently maximizes the usage of display area better than traditional hierarchical drawing. Comparing to the 3D type, RELT's advantages are due to its practical usability and desirable navigation assistance (to be discussed in the next section). In additional, it is not always necessary to visualize the whole hierarchical structure at once. RELT allows the user to define the number of levels to be viewed.

Figure 7: A RELT arrangement of the example music collection in Figure 5

4 RELT Navigation

4.1 Navigation Methods

The main potential motivation for information visualization is to assist information retrieval through effective navigation. The steps that lead to the right destination can usually be predetermined. With the help of clear visual structure, people can easily locate where they are. Navigation is essentially a vital criterion for assessing the effectiveness of a visualization method.

Touching (using a stylus or finger) and button click are two common ways for mobile information navigation. The former is more intuitive. People only need to touch certain part of the screen corresponding to the information that they want to access. Figure 8 illustrates how to navigate with the buttons on Nokia N95.

Figure 8: Controlling scheme for navigation

Only the center button and surrounding buttons are needed for RELT navigation. Surrounding buttons are used for direction controlling. For example, the user will go back to the parent of his current directory if the upper button is pushed. The current position will change to the left sibling if the left button is pushed. The center button is used for new Root selection. As shown, "Baroque" will move to the left corner if the center button is pushed.

4.2 Evaluation and Comparison with Current Approach

This section assesses the effectiveness of the RELT navigation and compares it with the commonly used menu bar method. First, the inherent difference between these two methods should be explained. To easily understand interpretation, problem is modeled under some preconditions and assumptions.

- The given example music collection can be represented as a full k-ary tree by applying traditional hierarchical drawing method, as illustrated in Figure 9. The example hierarchy has n levels.
- The number of levels that can be visualized on one screen using RELT is m ($m \leq n$).
- A unit is a branch which can be visualized by applying RELT at an instant in time.

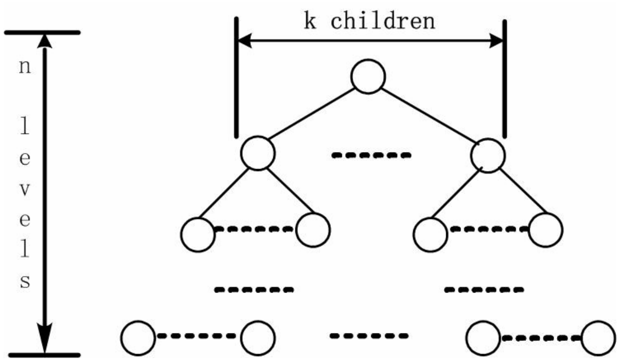

Figure 9: A tree structure where every node has 0 to k children

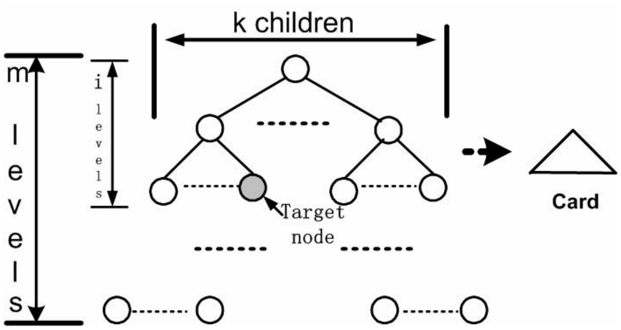

Figure 10: The branch visualized on RELT organized mobile interface

RELT can at most visualize *m* levels of full *k*-ary tree at a time. A part of the hierarchy that can be visualized on a mobile interface using RELT once is defined as a Card, following the terminology used in WML.

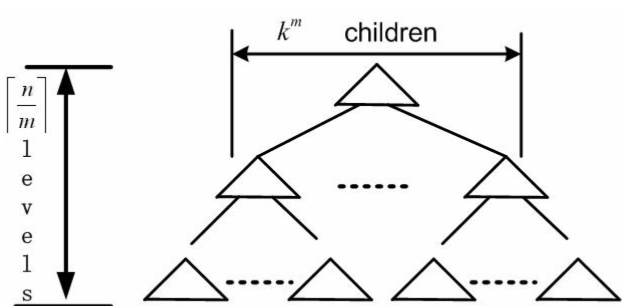

Figure 11: Hierarchy reduction – original tree in Figure 10 shrunk to $\left\lceil \frac{n}{m} \right\rceil$ levels of k^m-ary tree.

As Figure 11 illustrates, RELT has an enhanced navigation ability by reducing the size of the hierarchy. The hierarchy size reduction is achieved by increasing the amount of information to the whole tree or a large branch depending on the size of the tree that the user may wish to see at one glance.

The above discussion is a theoretical one. In reality, there may not be such large and complex music archives on personal mobile devices. The main advantage of the RELT approach is that we can pan to visualize any part (a good-sized branch) of the music structure with a reasonable size on one screen.

Tables 2 and 3 illustrate the number of intermediate nodes that the user may traverse when he/she wants to find certain the desirable music item (target node) in one music collection. Assume the target nodes locates at the i_{th} level and there are totally *j* nodes in the first *i* levels. In the tables, "Explicit" means that the user knows where the target node locates. "Implicit" indexed with $_w$ and $_b$ depict worst and best cases if the user has no idea about the target node's location. The navigation approaches of Tables 2 and 3 are touch-based and button-based respectively.

	Explicit	Implicit_w	Implicit_b
Menu (Touch)	i-1	j-1	i-1
RELT	0	0	0

Table 2: Comparison of RELT with touch-based menus

Table 2 shows that, using cascading menus to navigate through touches, the user has to touch *i-1* times (traverse *i-1* intermediate nodes) to arrive at the target node in the best case. The user only needs one touch only to arrive at the target (traverse 0 intermediate nodes) in RELT.

	Explicit	Implicit_w	Implicit_b
Menu (Button)	i-1	j-1	i-1
RELT	i-1	i-1	i-1

Table 3: Comparison of RELT with button-based menus

Table 3 shows that instead of jumping from the root node to the target node in touching-based cases, the user has to push buttons to arrive at the target node level by level. Using RELT, the user has to traverse i-1 intermediate nodes. Cascading menus work as well as RELT only in the "Explicit" and best "Implicit" cases.

5 Conclusion and future work

The improving mobile communication capability and faster processing speed allow people to access a large amount of information on mobile devices. With the availability of standard visual APIs, mobile visualization techniques become more sophisticated. Nowadays, visualization plays a significant role in offering intuitive information representation. This paper analyzes the current hierarchical information visualization approaches and was motivated by the following two observations:

- The two general approaches, connection and enclosure, are not suitable for mobile devices without proper adaptation.
- When both a desirable display structure and the maximum use of the display area are essential criteria, scaling down the traditional methods designed for desktop displays do not work well.

This paper has presented a new method RELT which combines the advantages of both the connection and enclosure approaches. This technique maximizes the screen usage by recursively partitioning the display area. The non-overlapping regions are arranged in such a way that maintains the explicit hierarchical relationships.

Several hierarchical information examples have been tested with encouraging results. Although this technique is still under refinement, we believe it will make a valuable tool for mobile hierarchical information visualization.

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