Boundary Labeling for annotated documents

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CHAPTER 1

Introduction

Whenever additional information neets to be inserted into an existing document without altering the original text, we can make use of annotations. They usually take the form of footnotes, which require only a minimal reference in the main text, and are used for a variety of reasons - for example, to provide additional information that would hinder the text's flow if inserted directly, or as a result of a commenting tool that is used for communication between an author and their editor. If a more obvious connection between the text and the referenced content is required, for example when lengthy comments are added, or if a change-tracking tool is used, the reference is often placed to the side of the document and visibly connected to the part of the text it is referring to. This style of annotation is easily implemented on virtual documents, since they can be hidden on demand, however if the annotations need to be included in a printed version, there are several issues that arise regarding readability of the final product and ambiguity of text-annotation assignments.

In this thesis, we will look at ways to use Boundary Labeling for this problem, which means that all annotations will be placed somewhere outside of the text they are referencing and will be visually connected to the feature they are referencing. (See also [3])

The guidelines on how to create suitable labelings are as follows: the connections should be as direct as possible, no important information should be obscured, and it should be easily discernable which Label belongs where. These three criteria easily come into conflict with one another, as the text usually is very dense and leaves little space for lines in between, yet one shouldn't allow them to pass through the text, as this makes the text harder to read.

1.1 Terminology and Fundamentals

Boundary Labeling (or equivalent concepts) can be applied to a space with different geometry or more dimensions, but this thesis will only concern itself with two-dimensonal,

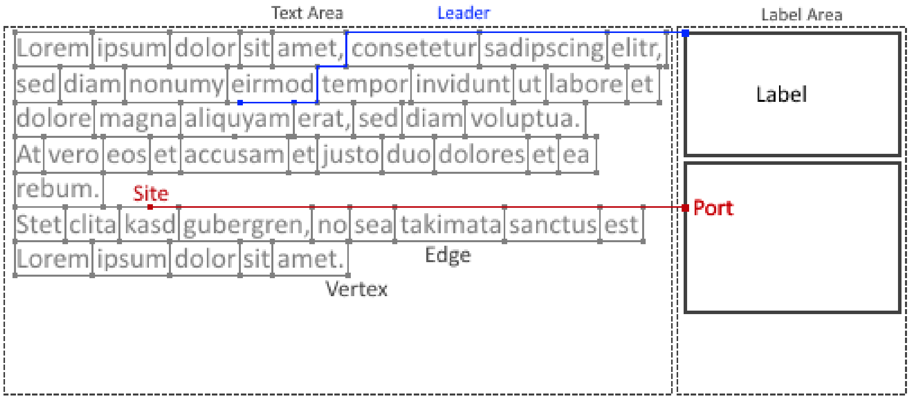

Figure 1.1: Illustrated guide to the labeling terminology

Euclidean space. To easily reference important concepts, some additional terminology will be introduced as well. (See Fig. 1.1 for a visual explanation)

A *graph* $G = \langle V, E \rangle$ is a tuple of *vertices* $V = \{v_1, v_2, ..., v_n\}$ and *edges* $E = \{e_1, e_2, ..., e_m\}$. A vertex v is a featureless object. Each edge e is a relation between two vertices $E \subseteq V \times V$. We call two vertices $u, v \in V$ *adjacent*, if the edge $e = (u, v) \in E$. A *path* $P = v_1, ..., v_h$ is an ordered sequence of vertices, where each vertex must have an edge connecting it to the subesquent one. *Depth-first search* is a searching algorithm on a graph G that starts at a given vertex $v \in V$ and explores the graph by traversing its edges as far as possible before backtracking, and continues to do so until a pre-defined goal is met.

Polylines are a connected series of *line segments*. Line segments are straight lines that contain each point between their starting and end point. *Labels* hold additional information and are represented as boxes containing this information. They are usually placed in the *label area* which is a rectangular area designated to hold labels. It is located next to of the bigger, rectangular *text area*, which contains the document's text and all *sites*, the points or objects that a label's information refers to. If multiple label areas exist on different sides of the text area, we speak of *multi-sided labeling*, otherwise we speak of *one-sided labeling*. We will be using one-sided labeling in our implementation. Some space was left in between the text and label area, to make connecting sites to their labels easier, which we will call the *routing area*. The site and the label are connected via a *leader*, a polyline that can be further classified by looking at the orientation of its segments: *O-Segments* run orthogonally to the border of the label area. *P-Segments* run parallel to the border of the label area, and as such must be combined with other segments for the leader to reach its destination. *S-Segments* are not required to have any particular orientation, and simply connect their start and ending points in a straight line. The leader's name is created by combining the name of the segments - for example, the blue leader from Fig 1.1 would be classified as an OPOPO-Leader. The location where a leader connects to the label is called the *port*. It can be restricted to pre-defined positions.

1.2 Related Work

Boundary labeling was first introduced by Bekos et al. in 2004 (see [3]), where both one-sided and multi-sided labelings with different leader types are looked into. They also showed that the optimal placement of arbitrarily-sized labels on two sides of the text area can be NP-hard by drawing comparisons to the Partition-Problem. However, a pseudo-polynomial solution exists for this problem, which was adapted to this variation of the problem.

Since then, several papers have been written about boundary labeling. One of these is [2], which looks into the readability of different leader styles. Interestingly, some leader styles perform quite well, despite the study's participants preferring others over them, with OPO-Leaders being both least preferred and the hardest to follow.

Another article using boundary labeling is [4] by Göetzelmann et al., which creates boundary labeling-style annotations along other methods to label different parts of three-dimensional figures, resulting in pictures similar to what could be found in a textbook. As this algorithm works in real-time, it is suitable for labeling interactive models and allows for user interaction.

Boundary labeling in text documents however, is rarely discussed, and only few papers exist about this topic. The programs that employ this style of annotation often also use rather simple algorithms, to mediocre results or make extensive use of the interactivity of a digital medium, showing annotations only on demand. However, the few papers that approach this topic add interesting information to the discussion.

The paper about the Luatodonotes-Package[5] uses several styles of drawing leaders, and came to the conclusion that leaders without bends are easier to follow, which fits with [2]'s observations, which ranks OPO- and PO-Leaders lower than other variants. However, most solutions proposed in [5] do not consider whether a path overlaps with text or not, which results in a decrease in readability. While we do not use the routing and leader styles introduced in this paper, the results can be used in comparisons regarding readability of the main text and ease of use of the different leader styles.

The thesis by Loose[7] on the other hand is based around only using the free space between lines and words, which produces longer leaders, and forces curves, but doesn't obscure any part of the text. The two different approaches in this paper were a clustering-based algorithm, which was previously described in [8], and a flow network-based approach. Several concepts of this paper, such as the graph-based strategy and the usage of a routing area will be adopted in our thesis and it is by far the biggest influence on our approach to the problem.

Lin et al.[6] use only OPO-Leaders that have their P-Segment located outside of the text area in their paper, but allow the leaders to use the text area's border on the opposite side of the label area to route upwards or down. This allows for more labels to be placed as close as possible to their leader's source, at the cost of increasing select leaders' length and placing some labels out of order. While this is an interesting way to avoid longer leaders in general, it is hard to combine with the graph-based routing that happens inside the text area, so we won't make use of it.

CHAPTER 2

The Algorithm

In our algorithm, the focus was put on keeping the text as readable as possible. This means that leaders aren't allowed to pass through words, which was implemented by enclosing each word in a bounding rectangle that leaders aren't allowed to pass through. The leaders should also be kept as short as possible, so we restricted them to always be moving toward the label, even if the direct route is unavailable.We also wanted to use the space available in the labeling area as efficiently as possible, so labels are placed as far up as possible in order to maximize the space available to future labels at the cost of increased leader length.

To create leaders that exclusively use the space not taken up by a word's bounding rectangle, we decided to use a graph similar to the one Loose [7] used. As each vertex represents a physical location, they will have co-ordinates associated with them, and the vertices representing the sites will hold additional information regarding its leader and label. The graph is constructed by placing vertices between the lines, located next to each corner of a word's bounding rectangle, with two consecutive words in a line sharing the two vertices associated with their adjacent corners. For the sites, we inserted an additional vertex above the center of the word, which will serve as the leader's starting point. After placing all vertices, we created edges between each vertex and the closest horizontal neighbour to both sides, and between nodes that are located exactly above or below each other, and exactly one line apart. (For a representation in Pseudocode, see Alg. 1)

In our labeling algorithm, we decided to work through the labels in the order they appear in the text, placing each as far up as possible, and skipping any label that would've required us place the label below its leader's source node. We also opted to use fixed ports located in the top left corner of each label, as this allowed us to unabiguously place annotations by only knowing their port location, which is equal to their leader's ending point. To not restrict the label's placement by the line spacing, we left a buffer zone between the text area and the label area, which allows us to place labels even further above to optimally use the available space. The algorithm's input consists of the Graph

```
Data: A text with annotations,stored as a String-Array
Result: A Graph (as described above)
initialization
foreach w in words do
    if w is annotation then
        v ←new Vertex(previousWord.getCenter())
        v.setAnnotation(w)
        Graph.addVertex(v)
        UpperVerticesList.addVertex(v)
    else
        if w is too big for the line then
            startNewLine()
            connectBasedOnPosition(UpperVerticesList)
            UpperVerticesList ←LowerVerticesList
            emptyList(LowerVerticesList)
        end
        v1 ←new Vertex(w.getTopLeft())
        v2 ←new Vertex(w.getTopRight())
        v3 ←new Vertex(w.getBottomLeft())
        v4 ←new Vertex(w.getBottomRight())

        Graph.addAll(v1,v2,v3,v4)
        UpperVerticesList.addAll(v1,v2)
        LowerVerticesList.addAll(v3,v4)
        Graph.createEdgeBetween(v1,v3)
        Graph.createEdgeBetween(v2,v4)
    end
end
```

Algorithm 1: Representation of the Graph-creation algorithm in pseudocode

G and a set of sites $V_{ann} \subset V$ which will be routed using a depth-first search algorithm, restricted to only selecting vertices located above or to the right of the current vertex, prioritizing moving up whenever possible. After the algorithm terminates, it returns a set with routing information for each vertex, which contains a Path $P = \{v_1, \cdots, v_n\}$, leading from the site to the text area's border, along with some additional information on how to draw the OPO-Segment that connects to the Label's port. If the routing for any given site failed, the path consists of a single vertex - the site. (For an illustration in Pseudocode see Alg. 2.)

```
Data: A single annotation's source and its Graph
Result: A List of vertices describing the Leader's Path
initialization
while currentVertex not at right text border do
    if (Graph.getTopNeighbourOf(currentVertex) ≠ null) ∧ ¬backtracking
      then
        Path.addVertex(currentVertex)
        currentVertex ← Graph.getTopNeighbourOf(currentVertex)

    else if Graph.getRightNeighbourOf(currentVertex) ≠ null then
        Path.addVertex(currentVertex)
        currentVertex ← Graph.getTopNeighbourOf(currentVertex)
        backtracking ← False
    else
        backtracking ← True
        repeat
            oldVertex ← currentVertex
            currentVertex ← Path.getLastEntry()
            Path.RemoveVertex(currentVertex)
        until currentVertex's Position is below oldVertex or Path is Empty

        if currentVertex not below oldVertex then //No path found
            break
        end
    end
end
```

Algorithm 2: The Depth-First-Search algorithm used in the program.

CHAPTER 3

Implementation

The program was written in Java 1.8.0u40, using JGraphT1.0.1[1] as graph library. Since we only want to create leaders that don't intersect with the text, the graph was created alongside the placement of the words on the canvas.

3.1 Challenges

CHAPTER 4

Evaluation and Testing

4.1 Data generation

4.2 Testing methods

4.3 Results

CHAPTER 5

Conclusion

5.1 Further notes

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