A TOOL FOR OLAP (ON-LINE ANALYTICAL PROCESSING) ON TEXT DOCUMENTS

by

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ABSTRACT

We want to automate the process of summarizing a collection of documents, and get an overall picture of the topics covered by the document collection. The summarized results should be easy to understand with simple visualization and able to get more details on selected topics by performing various operations. The purpose is to help users to save time on finding out interesting articles, and focus only on useful articles and conduct further analysis as they desire.

In order to achieve this goal, we developed the tool *Docs Summarizer*, where we introduced Online Analytical Processing (OLAP) into document set summarization. Our Tool can take a collection of documents as input, and apply analysis on them to generate a series of meaningful outputs. The outputs include a list of top k analysis level categories and a two-dimensional matrix chart. The users can do further exploration on the outputs by performing various operations.

Keywords: tool; Online Analytical Processing; summarizing documents; visualization results

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1: INTRODUCTION

1.1 Motivation

Travis is planning a trip for his two-week vacation, but he cannot decide where to go. He browses through several of his favourite blogs and tries to find articles related to interesting travel experiences. However, it is painful to go through each post and there is no guarantee when and where he can find what suits him. He is thinking that it would be great if there were a tool for him to input links of different blogs, and generate a summary for all posts automatically. The summary can be a list of categories ranked by its importance, so that he can pick some categories he is interested in and read more related posts.

Victor is the manager of a sales department. He asks each of his employees to collect feedbacks of their newest product, but ends up with a large number of text documents that contain customer/user reviews from different sources. He is now having a headache to sort out and to summarize all the opinions they gathered. It is time consuming if he reads each review one by one, and he wants to see the big picture of the overall feedback. It is hard to do the task manually. Victor thinks he should use some tools to automate the task. He would like to use the tool to analyze all review documents and get a list of ranked aspects from the review collection. Based on the given list of ranked aspects, he could conduct further analysis on the categories that need more attentions from him. It will be more efficient and effective than conducting the task manually.

To conclude, we see that there is a strong need for a text summarization tool, which can summarize a collection of text documents and help users to save time on finding out interesting articles. By using the tool, users can focus on useful articles only and conduct further analysis as they desire. Therefore, we developed the tool *Docs Summarizer* to achieve this goal.

1.2 Objectives

We want to automate the process of summarizing a collection of documents, and get an overall picture of the topics covered by the document collection. The summarized results should be easy to understand with simple visualization. In addition, users should be able to get more details on selected topics.

To achieve our goal, we introduced Online Analytical Processing (OLAP) into document set summarization (Chaudhuri & Dayal, 1997). OLAP is a category of applications that collects, processes and presents multidimensional data for decision support. OLAP applications allow users to conduct further explorations on data by providing functionalities such as drilling down and drilling up. The output of an OLAP application often displays in a matrix format. The dimensions form the rows and columns of the matrix, and the measures form the values of the matrix (Mailvaganam, 2007).

In our project, our tool *Docs Summarizer* performs the tasks described above by applying an OLAP solution to summarize a given collection of documents. Our solution has the following features:

- The summarized results are lists of categories, which cover the given collection of documents
- A list of categories is ranked by its importance
- A matrix chart, which provides further details for two selected categories, is presented to users.
- Users can explore more details by drilling down on selected categories.

1.3 Related Work

There are many researches conducted on the field of text summarization in the last half century. They can be roughly grouped into single-document summarization and multi-document summarization. We briefly introduce each area in this section.

There are two major methodologies proposed for the early work of single-document summarization. The first methodology emphasizes the frequencies of non-stop words, and those frequencies are treated as useful measures of word significance (Luhn, 1958). The second methodology proposed that sentence position indicates the relatively importance of each sentence; therefore, we can find out the possible topic sentence for an article (Baxendale, 1958). In recent decades, *Natural Language Processing* (NLP) becomes the mainstream approach for text summarization. Some major works include Naive-Bayes method with independence assumption (Kupiec, Pedersen & Chen, 1995) and some learning algorithm with no independence assumption, such as hidden

Markov model (Conroy & O'Leary, 2001), log-linear models (Osborne, 2002), and neural networks (Svore, Vanderwende & Burges, 2007).

The other area for text summarization is the *multi-document summarization*, where the main goal is to extract a single summary from multiple documents. SUMMONS is one of the summarization system developed by the NLP group at Columbia University (Mckeown & Radev, 1995). It is a template-driven system and is designed to work on a strict, narrow domain. The system tends to be problematic when it works on a generalized, broader domain. However, the issue was addressed and improved in later years by McKeown et al (McKeown, Klavans, Hatzivassiloglou, Barzilay & Eskin, 1999). The improved system employ techniques such as evaluating single words by their TD-IDF weighted scores and using single words synsets information from *WordNet* (Miller, 1995).

The other major application for *multi-document summarization* is MEAD, and MEAD is a large-scale system that aimed to work on general domains (Radev et al., 2004). Each document in MEAD is represented as a bag of words, and there are two stages to perform in the system. The first stage is topic detection, which groups articles describing the same event together. The second stage is to identify central sentences in each group, and the central sentence are outputted as the summarized results. We can see the two summarization systems distinguish themselves by aiming at different ranges of domain, and the summarized results from both systems are in paragraph style.

One of the other major categories for *multi-document summarization* is the topic-driven summarization. Topic-driven feature implies a dependency on queries, and different queries may lead to different summarization results. The reasoning behind is that different users with different information needs may require different summary of the same document (Carbonell & Goldstein, 1998). The main representations include Maximal Marginal Relevance (MMR) (Carbonell & Goldstein, 1998) and Graph Spreading Activation (Mani & Bloedorn, 1997).

Maximal Marginal Relevance treats each sentence or paragraph as a token and calculates a score by reward relevant sentences and punish redundant ones (Carbonell & Goldstein, 1998). The tokens with the highest score are presenting as the summary results. Graph Spreading Activation finds similarities and dissimilarities between pairs of documents using a graph-based method (Mani & Bloedorn, 1997). Each document is represented by a graph using nodes and edges, and the common nodes and different nodes between a pair of document graph are identified. The sentences with highest common score and highest different scores are output as the summarization results.

Our tool aims to perform *multi-document summarization*, and it differentiates itself by conducting *keywords summarization* instead of paragraph-style or headline-style summarization. In addition, we employ the TF-IDF technique, as it is consistent with language model in theory. However, we apply TF-IDF on the *category* of a single word instead of the single word itself. The argument is that, *comparing to a frequent single word, a frequent category is a* *better representation of a document*. The category hierarchy information is extracted from the external tool *WordNet* (Miller, 1995).

1.4 Organization of the Report

The rest of our report has four major sections. The next section contains detailed project description and major project screen shots for illustration. In Section 3, we first demonstrate our baseline solution and identify some potential problems associated with this solution, then introduce an improved version of solution to conquer some of the issues we encountered. Section 4 provides one interesting empirical use case studies by applying our solution on a real dataset. Finally, Section 5 concludes our project and lists possible future work to enhance project results.

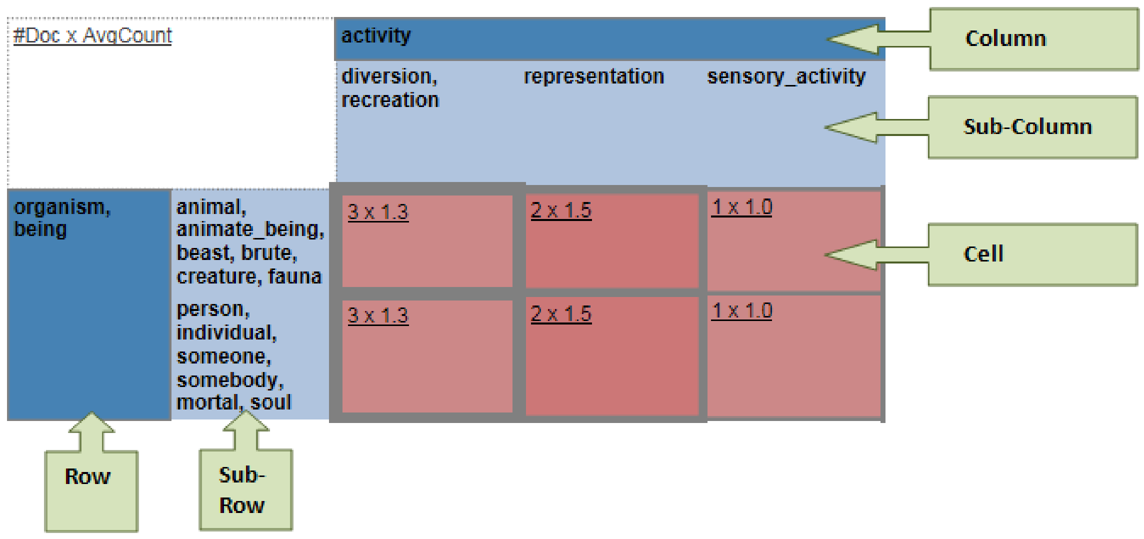
2: SPECIFICATION

In this chapter, we first introduce important terminologies that will be used throughout the report. Then, we present a detailed project description and major project screen shots for illustration. The main operations for our tool, *Docs Summarizer,* are also discussed in this chapter.

2.1 Terminology

Before we describe our tool in more details, we will introduce several terminologies which will be used throughout the report.

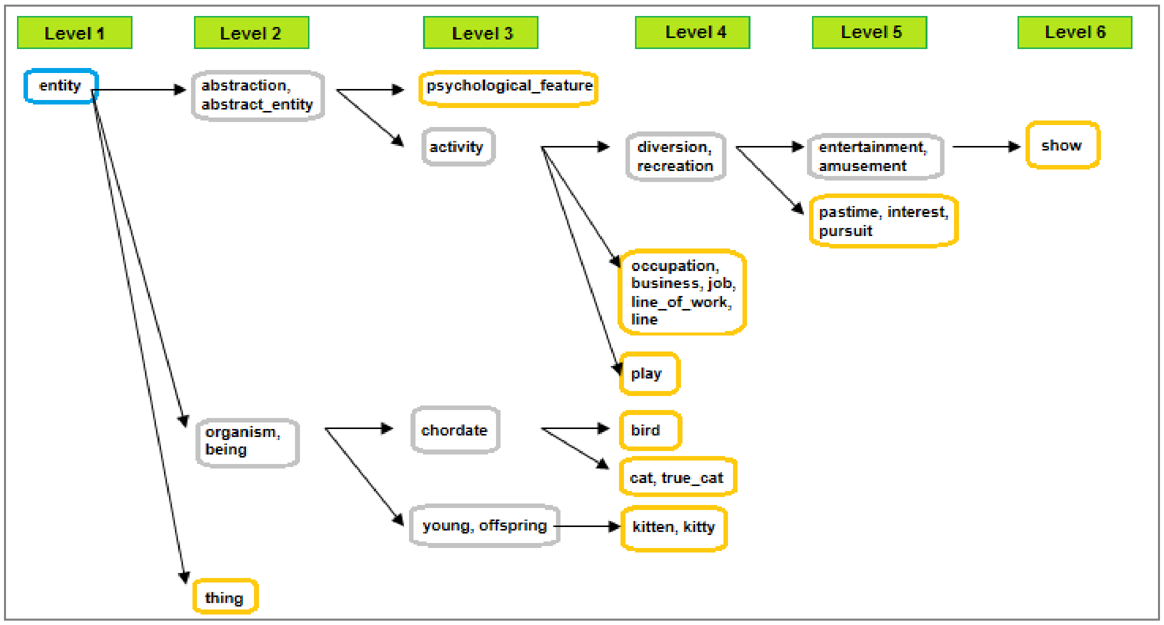
Figure 1 Example of a Matrix Chart and the Related Terminologies



- **Matrix chart**: A chart that summarizes a multidimensional dataset into a grid. Please refer to Figure 1 for an example of a matrix chart.

- **Row**: The vertical header of a matrix chart. Refer to the matrix chart in Figure 1, the row is in dark blue background color and the value of the row is “organism, being”.
- **Sub-Row**: The secondary vertical header of a matrix chart. Refer to the matrix chart in Figure 1, the sub-row is in light blue background, and there are two values for the sub-rows, which are “animal, animate-being, beast, brute, creature, fauna” and “person, individual, someone, somebody, mortal, soul”.
- **Column**: The horizontal header of a matrix chart. Refer to the matrix chart in Figure 1, the column has a dark blue background color, and the value of the column is “activity”.
- **Sub-Column**: The secondary horizontal header of a matrix chart. Refer to the matrix chart in Figure 1, the sub-column is in light blue background color, and there are three sub-column values, which are “diversion, recreation”, “representation”, and “sensory activity”.
- **Cell**: The grid of a matrix chart. We refer each cell by its sub-row and sub-column value pair. For example, we refer the cell at the left top corner in Figure 1 as pair (“animal, animate-being, beast, brute, creature, fauna”, “diversion, recreation”). Also, each cell in a matrix chart has a value. For example, the cell at the left top corner of the matrix chart in Figure 1 has value “3x1.3”.

Figure 2 Example of a Category Tree



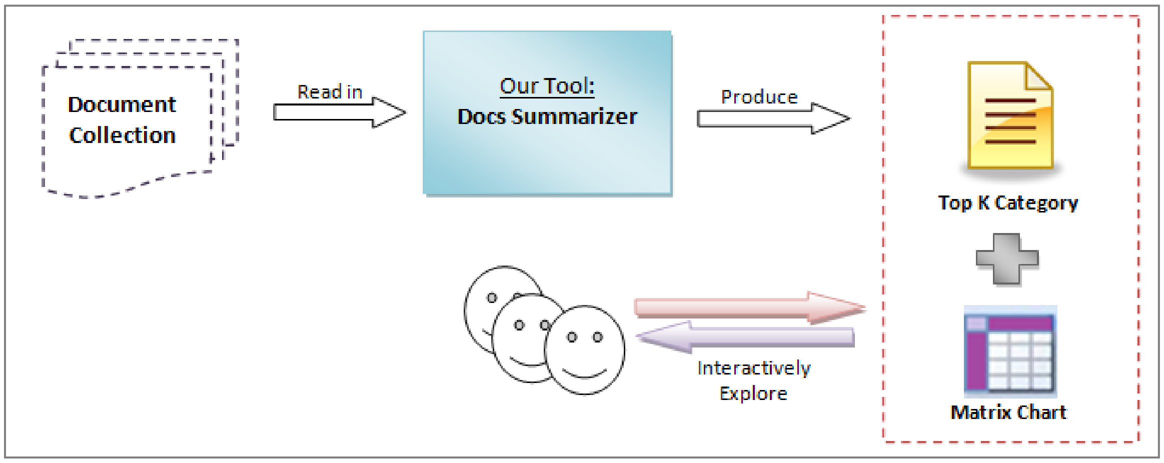
- **Category Tree**: A tree with a hierarchy of category. The root of the category tree is the most general category, comparing to its entire descendant. Each node in the tree must be a sub-category of its parent, and all of its children must be sub-categories of the node. We can see an example of a category tree in Figure 2. Note that the category tree grows from left to right instead of top to bottom. The root node, which is category “entity”, is circled by a blue border and is the parent/ancestor category of all other categories in the tree. The internal nodes, which are surrounded by gray borders, are sub-categories of their parents. Each internal node is also the parent/ancestor category for all of its children/descendants. The leaf nodes with orange borders are the most specific categories. Each of the leaf nodes is a sub-category of its parents, but has no sub-categories as children.

- **Category Level**: The level of nodes in a category tree. Category level is numbered in sequence starting from the tree root, and therefore the root has category level 1. The category level number of a node is the length of the path from the root to the node. The category level is increased by 1 when the length of the path is increased by 1. Refer to Figure 2, we see there are 3 nodes belonging to category Level 2: “abstraction, abstract entity”, “organism, being”, and “thing”. The deepest category level for the category tree in Figure 2 is Level 6, with only one node at this level.
- **Analysis Level**: The category level for the result category list generated by our tool.
- **Category Sub Tree**: A sub tree of the category tree. We can pick any node in the category tree to be the root of the category sub tree. The category sub tree contains all descendant nodes of the chosen root node.

2.2 Project Description

We will develop *Docs Summarizer*, which can interactively explore a collection of text documents and present users an overview of topics covered. We will provide visualization results so that users can capture main topics at a glance. Possible applications include blog reading tool, web page browsing tool, opinion summarizing tool, etc. All of these tools provide summarized results of

Figure 3 General Flow of using Docs Summarizer



a collection of text documents and allow users to explore on interesting facets intertactively.

To obtain an overall idea of the general flow of our tool, we can refer to Figure 3. The main purpose of the tool is to identify the top k categories from a given collection of documents, where k is an input parameter provided by users. Users can select two categories from the top k categories as the matrix chart row and column, and the tool will generate a 2D matrix chart as the visualization result. By default, the top two ranked categories are used as row and column, but users can select different categories and redraw the matrix chart. The sub-row values and sub-column values are the corresponding sub-categories of row and column categories. Each cell on the matrix chart represents documents covered by the specific pair of the sub-row value and sub-column value.

There are several operations available for *Docs* Summarizer. The purpose is to allow users to explore the result interactively. Users can increase the category level of sub-row or sub-column, in order to explore how documents in each cell scatter on a less general sub-row value or a less general sub-column value. By choosing a certain cell on the matrix chart, further drill down analysis can be applied to the documents associated with the cell. A new list of top k categories and a new matrix chart will be generated. More details on operations will be discussed in section 2.5.

2.3 Assumptions

For simplification, we assume that one file contains only one document, and the input for this tool is the directory of the entire document collection, which users would like to analyze.

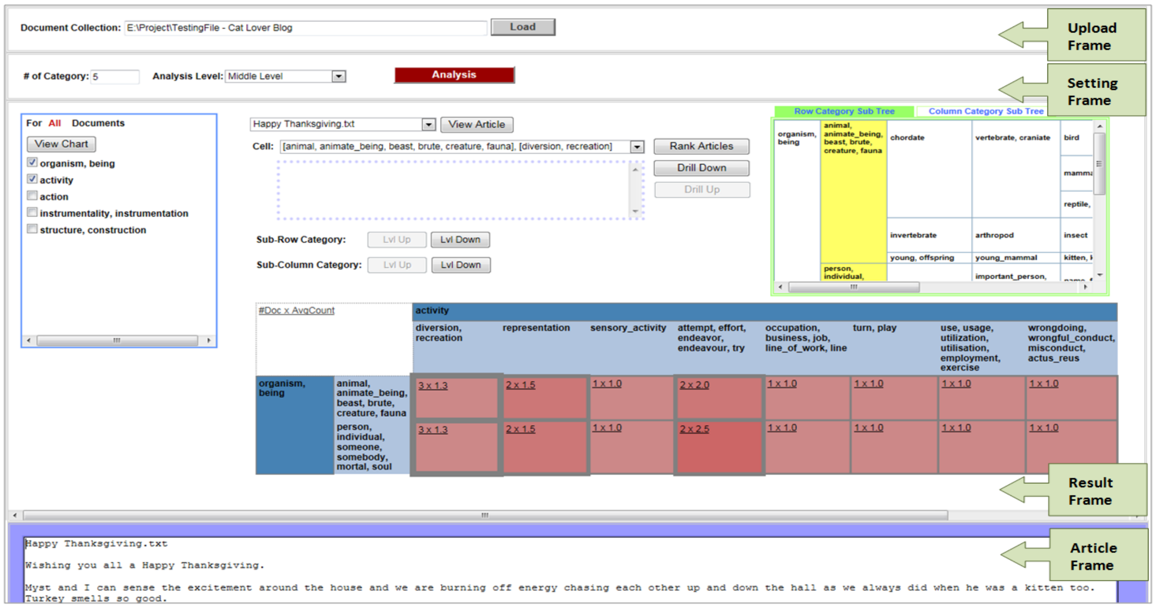
To keep our discussion simple, we do not consider phrases consisting of more than one word, such as “Stanley Park” or “Deer Lake”. We assume all words are separated terms and do not consider their orders as well.

We have a strong dependency on how words in the document collection are classified into categories, and how we build the category tree. For simplicity and result consistency, we use the external tool *WordNet* (Miller, 1995) to assign category to each word, and use it to build the category tree.

For the category tree we built for our tool, we further assume that there is no cycle contained in the tree, and a word may be included in the tree several times if it belongs to more than one category.

2.4 Application Interface

Figure 4 Docs Summarizer Interface



Document Collection: E:\Project\TestingFile - Cat Lover Blog

# of Category: 5 Analysis Level: Middle Level

For All Documents

- [✓] organism, being
- [✓] activity
- [ ] action
- [ ] instrumentality, instrumentation
- [ ] structure, construction

Happy Thanksgiving.txt

Cell: [animal, animate_being, beast, brute, creature, fauna], [diversion, recreation]

Sub-Row Category:

Sub-Column Category:

organism, being	animal, animate_being, beast, brute, creature, fauna	chordate	vertebrate, craniate	bird
				mamma
				reptile,
		invertebrate	arthropod	insect
		young, offspring	young_mammal	kitten, k
	person, individual,		important_person,	

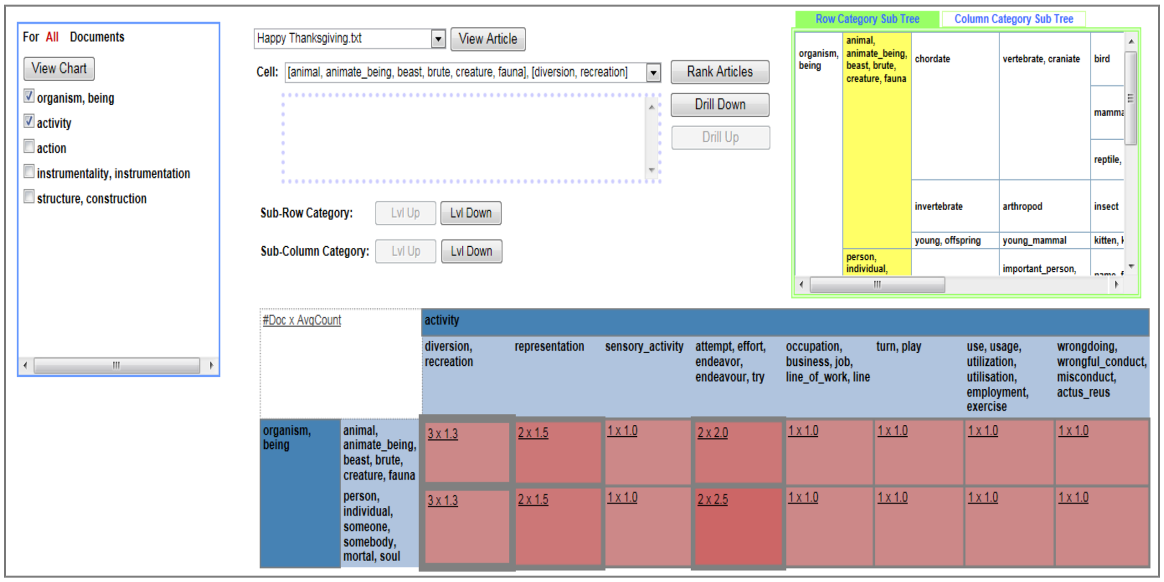
#Doc x AvgCount		activity							
		diversion, recreation	representation	sensory_activity	attempt, effort, endeavor, endeavour, try	occupation, business, job, line_of_work, line	turn, play	use, usage, utilization, utilisation, employment, exercise	wrongdoing, wrongful_conduct, misconduct, actus_reus
organism, being	animal, animate_being, beast, brute, creature, fauna	3 x 1.3	2 x 1.5	1 x 1.0	2 x 2.0	1 x 1.0	1 x 1.0	1 x 1.0	1 x 1.0
	person, individual, someone, somebody, mortal, soul	3 x 1.3	2 x 1.5	1 x 1.0	2 x 2.5	1 x 1.0	1 x 1.0	1 x 1.0	1 x 1.0

```
Happy Thanksgiving.txt

Wishing you all a Happy Thanksgiving.

Myst and I can sense the excitement around the house and we are burning off energy chasing each other up and down the hall as we always did when he was a kitten too.
Turkey smells so good.
```

The Docs Summarizer interface consists of four frames: Upload Frame, Setting Frame, Result Frame, and Article Frame. Please refer to Figure 4 to see a real case example.

- The Upload Frame allows users to load document collection by providing the collection directory.
- The Setting Frame allows users to adjust settings of analysis level and the number of categories to be generated in the analyzed result.
- The Result Frame shows the visualization result of the document collection, and some control elements for users to interact with the result. Please refer to Figure 5 for an enlarged screen shot of the Result Frame.

Figure 5 Enlarged Screen Shot of Result Frame



For All Documents

View Chart

- [✓] organism, being
- [✓] activity
- [ ] action
- [ ] instrumentality, instrumentation
- [ ] structure, construction

Happy Thanksgiving.txt | View Article

Cell: [animal, animate_being, beast, brute, creature, fauna], [diversion, recreation]

Rank Articles | Drill Down | Drill Up

Sub-Row Category: Lvl Up | Lvl Down

Sub-Column Category: Lvl Up | Lvl Down

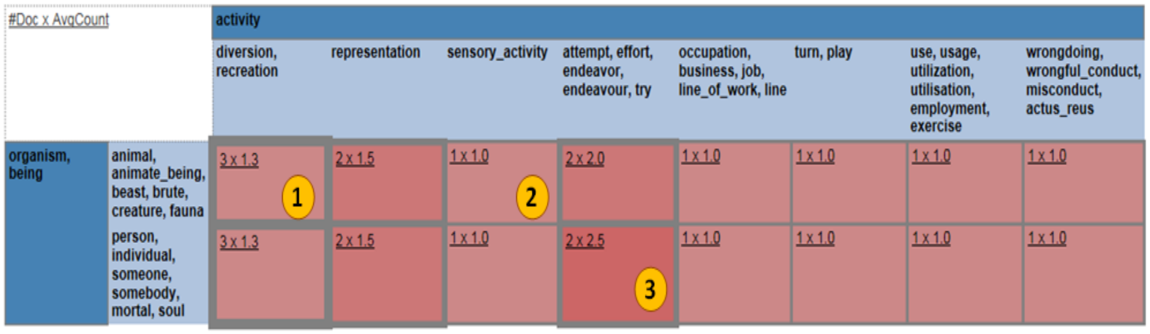
Row Category Sub Tree | Column Category Sub Tree

organism, being	animal, animate_being, beast, brute, creature, fauna	chordate	vertebrate, craniate	bird
				mamma
				reptile,
		invertebrate	arthropod	insect
		young, offspring	young_mammal	kitten, k
	person, individual,		important_person,	name, f

#Doc x AvgCount		activity							
		diversion, recreation	representation	sensory_activity	attempt, effort, endeavor, endeavour, try	occupation, business, job, line_of_work, line	turn, play	use, usage, utilization, utilisation, employment, exercise	wrongdoing, wrongful_conduct, misconduct, actus_reus
organism, being	animal, animate_being, beast, brute, creature, fauna	3 x 1.3	2 x 1.5	1 x 1.0	2 x 2.0	1 x 1.0	1 x 1.0	1 x 1.0	1 x 1.0
	person, individual, someone, somebody, mortal, soul	3 x 1.3	2 x 1.5	1 x 1.0	2 x 2.5	1 x 1.0	1 x 1.0	1 x 1.0	1 x 1.0

- The Article Frame displays document content selected by users. A user can choose interesting document from the collection to read, and the frame will only display one document at a time.

Figure 6 Enlarged Screen Shot of a Matrix Chart



#Doc x AvgCount		activity							
		diversion, recreation	representation	sensory_activity	attempt, effort, endeavor, endeavour, try	occupation, business, job, line_of_work, line	turn, play	use, usage, utilization, utilisation, employment, exercise	wrongdoing, wrongful_conduct, misconduct, actus_reus
organism, being	animal, animate_being, beast, brute, creature, fauna	3 x 1.3 1	2 x 1.5	1 x 1.0 2	2 x 2.0	1 x 1.0	1 x 1.0	1 x 1.0	1 x 1.0
	person, individual, someone, somebody, mortal, soul	3 x 1.3	2 x 1.5	1 x 1.0	2 x 2.5 3	1 x 1.0	1 x 1.0	1 x 1.0	1 x 1.0

One of the major results for our tool is the matrix chart in the Result Frame. We use the enlarged matrix chart in Figure 6 for illustration, and we label three cells as cell 1, cell 2, and cell 3 for the ease of reference. The column and row values are selected categories, and the sub-column and sub-row values are sub-categories associated with the column and row categories. For each cell, it has a value in the form of "*number of documents belonging to the cell* x *the average count of the times that <u>the sub-row value</u> and <u>sub-column value</u> <u>appear together</u> in each document*". For example, we see that the value for cell 1 is "3x1.3", and cell 1 has a sub-row value "animal, animate-being, beast, brute, creature, fauna" and a sub-column value "diversion, recreation". We can interpret the value of cell 1 as the following: "There are three documents that contain both the sub-categories 'animal, animate-being, beast, brute, creature, fauna' and 'diversion, recreation'. Consider the two sub-categories as a pair. We count the number of times that the sub-category pair occurs in each of the three documents. The average count, which is total number of times that the sub-category pair occurs divided by total number of documents, is 1.3".

In the matrix chart, the border width of each cell reflects the number of documents belonging to it, and the background colour of each cell reflects its relative importance comparing to all other cells in the matrix chart. The thicker the border means the larger number of documents, and the darker the background colour means the greater importance of the cell. In order to become more important, the sub-category pair of a cell needs to have a higher average appearance rate in the associated documents. For example, in Figure 6, we see that there are three documents containing the sub-category pair in cell 1, while there is only one document containing the sub-category pair in cell 2. Therefore, the border for cell 1 is thicker than cell 2. By looking at the average count of times that the sub-category pair occurs, we see that cell 3 has a higher average count than cell 1 and cell 2. Therefore, it has a darker background colour than the other two cells.

2.5 Application Operations

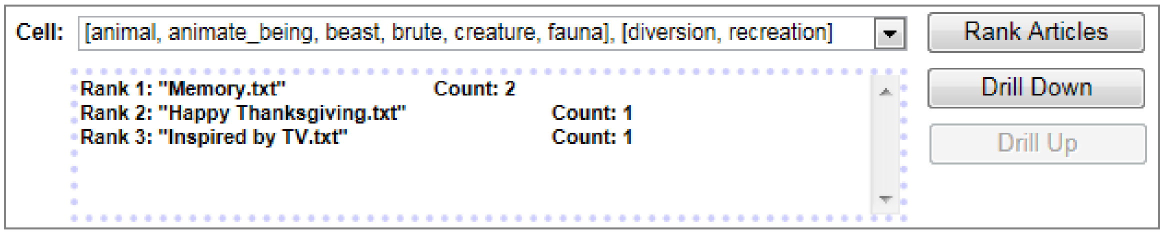
There are several operations available for our tool, and we will describe the function of each in the section. Here is a list of our five main operations:

- Redraw matrix chart by selecting two categories from the top k categories list.
- View full article by selecting an article name.
- For each cell of the matrix chart, we can rank articles according to their contributions, drill down for further analysis, or drill back up.
- For sub-row and sub-column of the matrix chart, we can increase their category levels, or decrease their category levels back to the initial level.
- View category sub trees for the row category and column category of the matrix chart.

2.5.1 Redraw Matrix Chart

Instead of using default categories, which is the top two ranked categories among the top k categories list, the user can select any other two categories from the top k categories list and generate a new matrix chart.

Figure 7 List of Available Cells and Available Operations



[animal, animate_being, beast, brute, creature, fauna], [diversion, recreation]

```
Rank 1: "Memory.txt"               Count: 2
Rank 2: "Happy Thanksgiving.txt"            Count: 1
Rank 3: "Inspired by TV.txt"                Count: 1
```

2.5.2 View Article

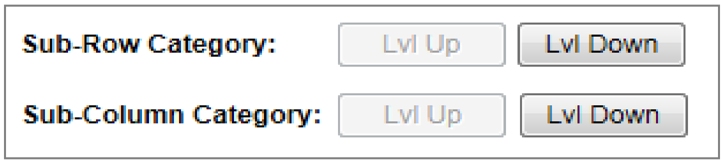
The titles of all articles from the input document collection are listed in a dropdown menu. The users can choose any document title from the dropdown menu to view the full document at the Article Frame below.

2.5.3 Operations on Cells of the Matrix Chart

We refer each cell by the pair of its sub-row value and sub-column value. The value pair of each cell is listed in a dropdown menu. Refer to Figure 7, we can see an example of value pair of a cell as “animal, animate-being, beast, brute, creature, fauna” and “turn, play”. Other possible value pair of a cell can be “person, individual, someone, somebody, mortal, soul” and “occupation, business, job, line of work, line”.

After selecting a cell, there are three types of operations to perform. We can rank articles belonging to the cell according to their contributions. The contribution is the count of times that the cell value pair appears in one document. For the chosen cell in Figure 7, the value pair appears in document “Memory.txt” two times, which has a higher appearance frequency comparing to the other two documents. Therefore, it is ranked as the top contributor to the chosen cell.

Figure 8 Operations on Sub-Row and Sub-Column

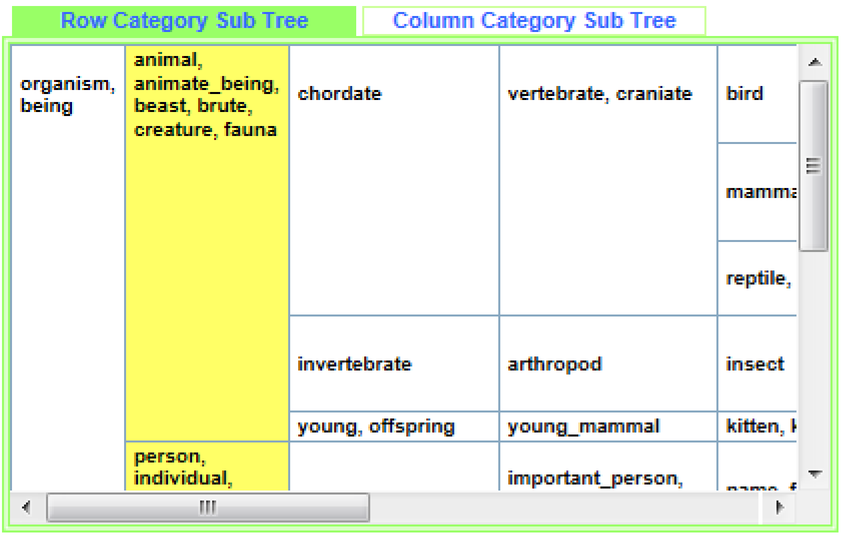


We can also drill down on a cell for further analysis. When we perform drilling down analysis on a chosen cell, our tool will reflect the change by regenerating the list of top k categories and a new matrix chart in the Result Frame. Finally, we can drill the cell up until it is back to its initial level. Refer to Figure 7, the “Drill Down” button will grey out after we perform drilling down on a single document, since further drill down operation does not make sense on a single document. For a similar reason, the “Drill Up” button will grey out when the cell is drilled up to its initial level.

2.5.4 Operations on Sub-Row and Sub-Column of the Matrix Chart

There are two operations to perform on each sub-row and sub-column of the matrix chart. We can increase the category levels of the sub-row and/or sub-column to see how documents scatter on less general sub-categories. We can also decrease the category levels until they are at their initial levels. Refer to Figure 8, users can adjust the category levels by clicking the enabled buttons. The “Lvl Down” buttons will grey out when the current sub-category level is the least general sub-categories level, and the “Lvl Up” buttons will grey out when the current sub-category level is same as its initial sub-category level.

Figure 9 Category Sub Tree Chart



organism, being	animal, animate_being, beast, brute, creature, fauna	chordate	vertebrate, craniate	bird
				mamma
				reptile,
		invertebrate	arthropod	insect
		young, offspring	young_mammal	kitten,
	person, individual,		important_person,	

2.5.5 View Category Sub Tree

In order to give users an overall idea on the row and column category hierarchy, we provide one category sub tree chart for each. We can refer to Figure 9 for an example of category sub tree chart. The root of the row category sub tree is the row category, and the root of the column category sub tree is the column category. Refer to the example in Figure 9, the category "organism, being" has two sub-categories, which are "<u>animal, animate-being, beast, brute, creature, fauna</u>" and "<u>person, individual, someone, somebody, mortal, soul</u>". For the sub-category "<u>animal, animate-being, beast, brute, creature, fauna</u>", it has three children with less general sub-categories: "Chordate", "invertebrate", and "young, offspring". Note that only the categories applicable to our document collection are part of the category trees, and the current levels of sub-categories for sub-row and sub-column are highlighted in yellow. Users can select to view category sub tree for row or column category by switching the tab at the top of the chart.

3: ALGORITHMS

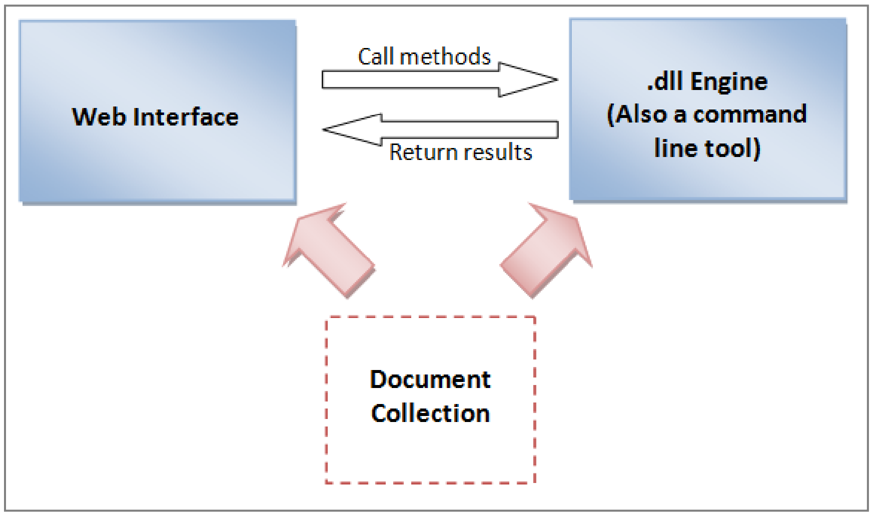
In this chapter, we demonstrate our baseline solution and identify some potential problems associated with this solution. We then introduce an improved version of solution to conquer some of the issues we encountered.

3.1 A Baseline Approach

We propose a baseline solution for our tool in this section. First, we illustrate our tool structure and introduce the overview of our algorithm. Then, we break down the algorithm into several detailed steps and discuss each of them in depth.

3.1.1 Tool Structure

Figure 10 Docs Summarizer Components and Their Interactions

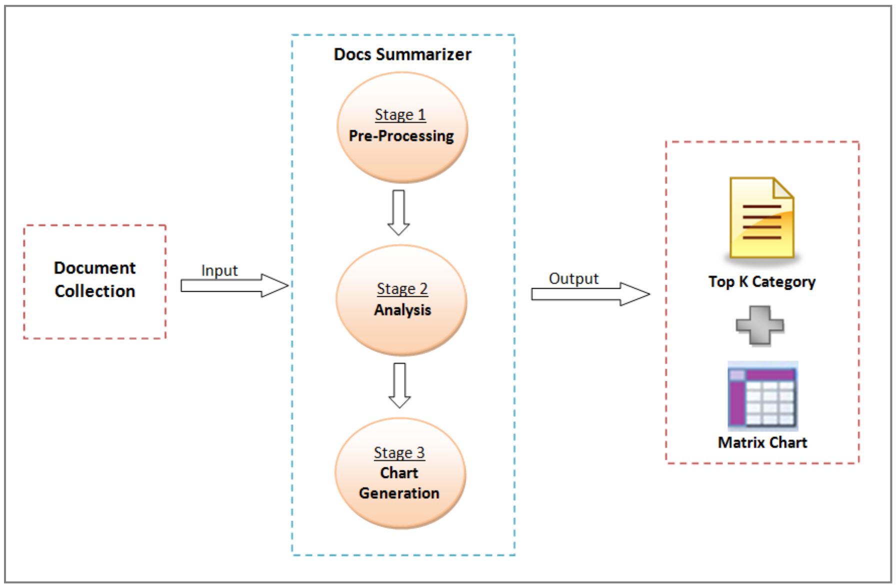


There are two components for *Docs Summarizer*. One is the front-end interface while the other one is the back-end engine. Refer to Figure 10, the front-end component is the web interface which allows users to interact with our tool. The back-end component is the dynamic-link library (dll) engine, which provides all necessary functions to perform tasks in our tool. Note the engine component is also a command line tool itself.

We can also refer to Figure 10 for interactions between the two components. Both of them have access to the input document collection directly. The web interface component sends all requests to the engine component, and the engine component respond with the result data.

3.1.2 Algorithm Overview and Framework

Figure 11 Flow of the Three Stages in Baseline Algorithm



The main purpose of the algorithm is to identify the top k categories in the *analysis level* from a given collection of documents, where k and *analysis level* are inputs from users. Then, we will use the top k categories to generate visualization results for user interaction. In order to achieve this goal, we divided the task into three stages: the *Pre-Processing Stage*, the *Analysis Stage*, and the *Chart Generation Stage*. We can refer to Figure 11 for the stage flow, and the detailed steps for each stage are listed at the end of this section.

At the *Pre-Processing Stage*, our tool read in the input document collection. For each document in the collection, we treat it as a bag of words. For each word, we convert it to its original form. As an example, “teach” is the original form for words “taught” and “teaches”. After we convert each word to its original form, the second step is to screen out the *quality* words, which are all nouns and all verbs.

Next, we use the external tool *WordNet* to build up a category tree on top of the collection of quality words and assign category level to each node. Each quality word is a leaf node in the category tree, and we use *WordNet* to look up the category hierarchy for each quality word and build the category tree accordingly. Note that sometimes a quality word might belong to more than one category. In this case, we include all of its categories instead of trying to analyze the document context.

After we built up the category tree for all quality words from the document collection, we progress to the *Analysis Stage*. We assign score to each category in the analysis level of the quality words, and then we aggregate scores for all categories in the analysis level and rank them in descending order based on a formula of the aggregated scores and documents coverage.

Finally, at the *Chart Generation Stage*, we generate a result ranking of top k categories in the analysis level where k and analysis level are inputs from users. Given the top k categories, our tool generates a matrix chart using the top two ranked categories. Users can explore the results interactively by conducting operations introduced in chapter 2.5.

Each of the three stages in Figure 11 can further divide into several steps, which are listed below. More details are provided in following sections.

Stage 1: the Pre-Processing Stage

Step1: Upload the document collection

Step2: For the input document collection, screen out all quality words, which are nouns and verbs in their original form. The result for each document is saved as a bag of quality words.

Step 3: Build a category tree on top of all quality words and assign category level to each node. We use *WordNet* as the reference tool to look up category hierarchy for each quality word.

Stage 2: the Analysis Stage

Step 4: Look up the analysis level categories for all quality words in the input document collection.

Step 5: Calculate ntf-idf score for the analysis level categories of all quality words in the input document collection.

Step 6: Generate top k analysis level categories based on a formula of aggregated analysis level category ntf-idf score and documents coverage

Stage 3: the Chart Generation Stage

Step 7: Generate information associated with the two selected categories in order to produce the result matrix chart

Step 8: Generate the result matrix chart

3.1.3 Pre-Processing

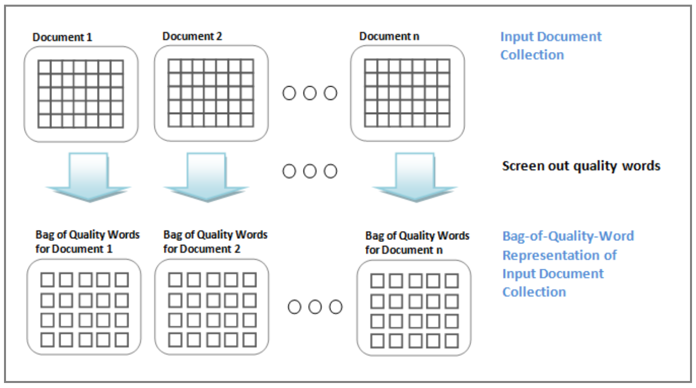
Step1: Upload the document collection

Upload the input collection of documents into memory for later analysis.

Step2: For the input document collection, screen out all quality words, which are nouns and verbs in their original form. The result for each document is saved as a bag of quality words.

For each input document, we select only nouns and verbs and convert each of them to its original form. We use the external tool *WordNet* to determine the part of speech for each word, and convert recognized nouns and verbs to their original form.

Figure 12 Screen out Quality Words for Input Document Collection


Document 1
Document 2
Document n
Input Document Collection
Screen out quality words
Bag of Quality Words for Document 1
Bag of Quality Words for Document 2
Bag of Quality Words for Document n
Bag-of-Quality-Word Representation of Input Document Collection

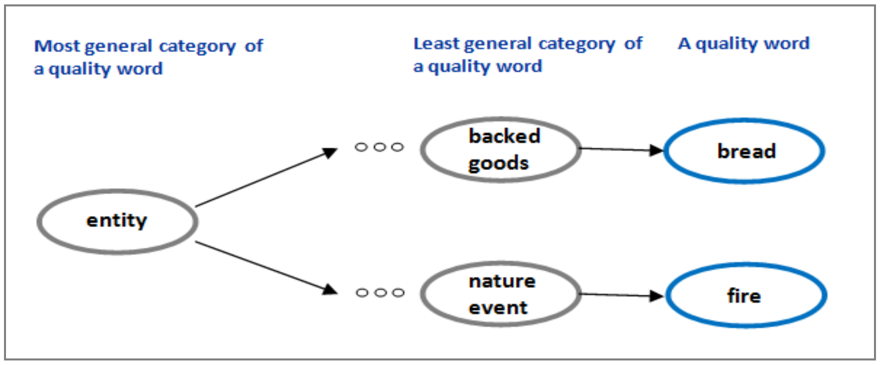
Then, each document is represented as a bag of quality words, which implies that the order of quality words is not important. We can refer to Figure 12 to illustrate this step.

In addition to producing the representation of each document in the input collection, we also generate a list of unique quality words appeared in the document collection.

Step 3: Build a category tree on top of all quality words and assign category level to each node. We use *WordNet* as the reference tool to look up category hierarchy for each quality word.

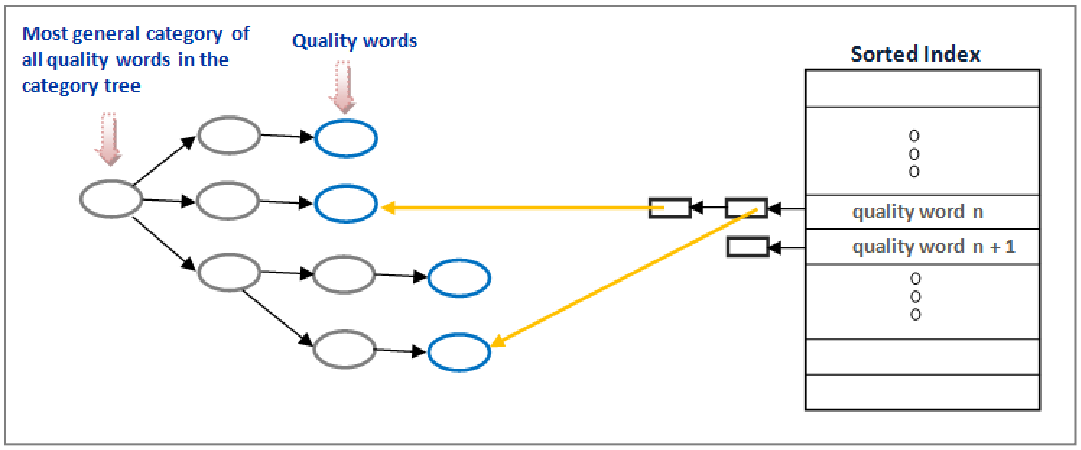
For each quality word, we need to identify its category hierarchy from the least general level to the most general level. The process is repeated on all unique quality words in the input document collection, and *WordNet* is the tool we employed to identify category hierarchy for each quality word.

Figure 13 A Category Hierarchy Example from WordNet


Most general category of a quality word
Least general category of a quality word
A quality word
entity
backed goods
bread
nature event
fire

We can refer to Figure 13 to see an example we exacted from *Wordnet*. For the quality word “bread”, it has a parent category “backed goods”, and a root category “entity”. To see another example, the least general category for the quality word “fire” is “nature event”, and the most general category for this quality word is “entity”, which is a shared category tree root with the quality word “bread”.

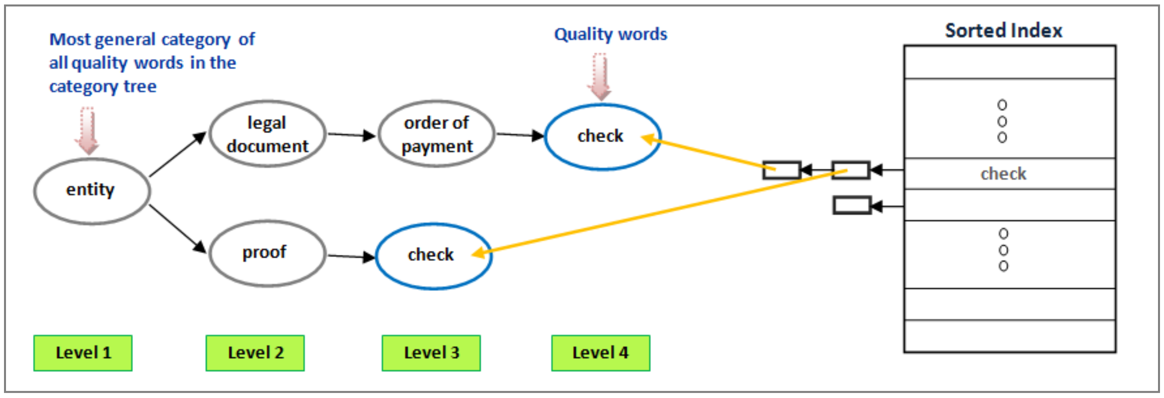
Figure 14 Structure of a Category Tree with Sorted Index


Most general category of all quality words in the category tree
Quality words
Sorted Index
quality word n
quality word n + 1

In order to look up the category hierarchy for any quality word in a more efficient manner, we build a category tree on top of the list of unique quality words in the input document collection. We can refer to Figure 14 to see the category tree structure. Each quality word is a leaf node, and we can look up more general categories by tracing up the tree. The tree root is the most general category for all the quality words in the tree.

A quality word may belong to more than 1 category. If a quality word has *n* parent categories, then *n* leaf nodes will be added into the tree. Each of the *n* leaf node is linked by a sorted index for fast access. The sorted index contains all unique quality words in the input document collection, and each quality word associates with a linked list. Each node of the linked list points to the quality word node in the category tree. The quality word, which belongs to a large number of categories, has a longer linked list. We can refer to Figure 14 to see the structure of the category tree with a sorted index.

Figure 15 A Concrete Example of a Category Tree with Sorted Index



We can refer to Figure 15 to see a concrete example. The quality word “check” has two sets of definition; therefore, it has two sets of category hierarchy. One path of the category hierarchy from the least general category to the most general category is “check”, “order of payment”, “legal document”, and “entity”. The other path is “check”, “proof”, and “entity”. In this example, we need to add two leaf nodes with value “check” into the tree, and each of the category hierarchy is represented by the branch path to the tree root. Then, we insert quality word “check” to the sorted index table and create a linked list with two nodes. Each of the node points to a different “check” leaf node in the tree. By constructing the category tree with sorted index, we can look up quality words and their hierarchy categories quickly and easily.

When we insert a node into the tree, a category level number is assigned to it. The most general category level is “1”, and the next less general category level is “2”. The category level is increased by 1 as we navigate one level down in the tree. The assignment continues until we reach the tree leaf, which is the quality word itself. We can refer to Figure 15 to see the category tree with category level assigned for each node.

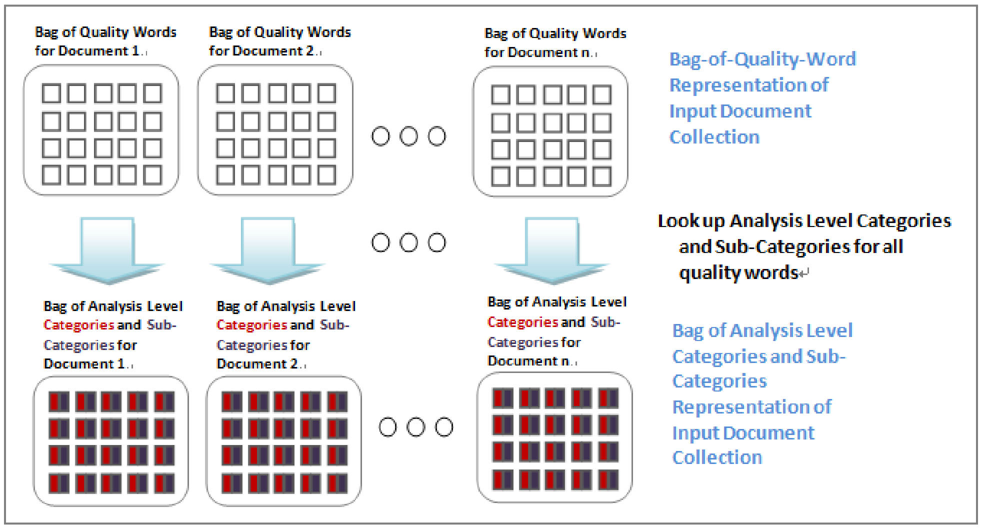
The purpose of assigning category level is to make sure we can compare all quality words in the collection of documents at the same scale. For example, a document may have both “apple” and “fruit” appeared. Without converting them to the same category level, we will count “apple” once and “fruit” once. If we convert both of them to the same category level, “food” as an example, then we will have 2 counts for “food”. The *analysis level*, which is the category level to perform analysis, is an input from the user.

3.1.4 Generating Top K Categories

Step 4: Look up the analysis level categories for all quality words in the input document collection.

In each document, we loop through all quality words, which are recognized nouns and verbs in their original forms. The purpose is to look up the *analysis level categories*, as well as the *analysis level sub-categories*. The *analysis level sub-categories* are the categories with their category level equal to analysis level plus 1. The reason for tracking the analysis level sub-categories is

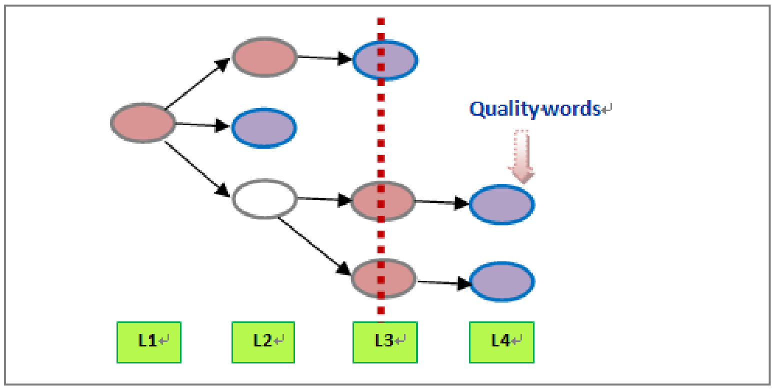
Figure 16 Look up Analysis Level Categories and Sub-Categories for All Quality Words


Bag of Quality Words for Document 1
Bag of Quality Words for Document 2
Bag of Quality Words for Document n
Bag-of-Quality-Word Representation of Input Document Collection
Look up Analysis Level Categories and Sub-Categories for all quality words
Bag of Analysis Level Categories and Sub-Categories for Document 1
Bag of Analysis Level Categories and Sub-Categories for Document 2
Bag of Analysis Level Categories and Sub-Categories for Document n
Bag of Analysis Level Categories and Sub-Categories Representation of Input Document Collection

that we use them as sub-row and sub-column values in the result matrix chart. We can refer to Figure 16 for an illustration. The red box in Figure 16 represents the analysis level categories, while the purple box represents the analysis level sub-categories.

If a quality word has more than one analysis level category, we include all of them instead of trying to do content analysis. In addition, if the quality word has its least general category level smaller than the analysis level, then we treat the quality word as the analysis level sub-category, and treat its parent node as analysis level category.

Figure 17 An Example of Selected Analysis Level Categories and Sub-Categories



We can refer to Figure 17 to see an example. Suppose we set the analysis level to “3”, the analysis level categories in Figure 17 are in red colour, and the analysis level sub-categories are in purple colour. Note that the least general category level of the quality word located in the second branch of the tree is “2”, which is smaller than the analysis level “3”. Therefore, we treat the quality word located in the second branch as analysis level sub-category, and we treat its parent as analysis level category.

Step 5: Calculate ntf-idf score for the analysis level categories of all quality words in the input document collection.

We need to calculate the normalized tf-idf score for the analysis level categories in each document. The analysis level is an input from users. Category level 1 represents the most general category. As the category level increases, the category becomes less general.

In order to calculate the normalized tf-idf, we need to calculate its normalized term frequency (ntf) and Inverse Document Frequency (idf). The reason to calculate a normalized term frequency instead of a pure term frequency is to avoid favoring longer documents. To compute normalized term frequency, we use the formula listed below, where *t* represents for “analysis level category” and *d* represents for “docuement”.

$$\mathrm{ntf}_{\mathrm{t,d}} = \mathrm{a} + (1 - \mathrm{a}) \frac{\mathrm{tf}_{\mathrm{t,d}}}{\mathrm{tf}_{\mathrm{max}}(\mathrm{d})}$$

For each document *d*, let the maximum term frequency be the analysis level category with the highest frequency count. To represent this in a math formula, we have $\mathrm{tf}_{\mathrm{max}}$ (*d*)=$\max_{(\tau\in d)}$ $\mathrm{tf}_{(\tau,d)}$, where *τ* ranges over all analysis level categories in *d*. For each analysis level category *t* in a document, we compute its normalized term frequency and *a* is a smoothing factor which we set to 0.4 here.

$$\mathrm{ntf}_{\mathrm{t,d}} = 0.4 + 0.6 \times \frac{\mathrm{tf}_{\mathrm{t,d}}}{\mathrm{tf}_{\mathrm{max}}(\mathrm{d})}$$

After we compute the ntf for each quality word in all documents, the next thing is to calculate the Inverse Document Frequency (idf). The purpose is to measure its general importance of a certain analysis level category. The formula to compute idf is listed below.

$$\mathrm{idf}_{\mathrm{t}} = \log \frac{N}{\mathrm{df}_{\mathrm{t}} + 1}$$

In this formula, *N* is the total number of documents in the collection, and df_t is the document frequency for the analysis level category *t*. We define the document frequency as the total number of documents in the collection which contain the analysis level category. The reason to plus 1 on df_t in the denominator is to make a correction to the case when there is no document contained a certain analysis level category t. We prevent the error caused by the number of documents divided by zero.

Finally, we can compute the ntf-idf for *each* analysis level category in *each* document using the previous results. We gain ntf-idf by using the normalized term frequency and multiple it by the inverse document frequency. The higher score for the ntf-idf means the higher normalized term frequency and the lower document frequency. Thus, the analysis level category is more important. The formula is listed below.

$$\mathrm{ntf} - \mathrm{ifd} = \mathrm{ntf}_{\mathrm{t,d}} \times \mathrm{idf}_{\mathrm{t}}$$

Step 6: Generate top k analysis level categories based on a formula of aggregated analysis level category ntf-idf score and documents coverage

First, we need to aggregate the ntf-idf score for the analysis level categories. For each analysis level category, we sum up the total ntf-idf score. We get a list of unique categories, and each one is associated with its total ntf-idf score. We refer the aggregated score for each category as *category score*.

We need to produce a set of k categories which satisfy two requirements. First, each category in the set needs to be frequent. Next, each of the k-categories needs to cover as many documents as possible. We will determine the *importance* of a category using its category score and multiply it by the number of documents being covered. The formula is listed below.

$$importance = \text{category score } \times \text{number of documents covered}$$

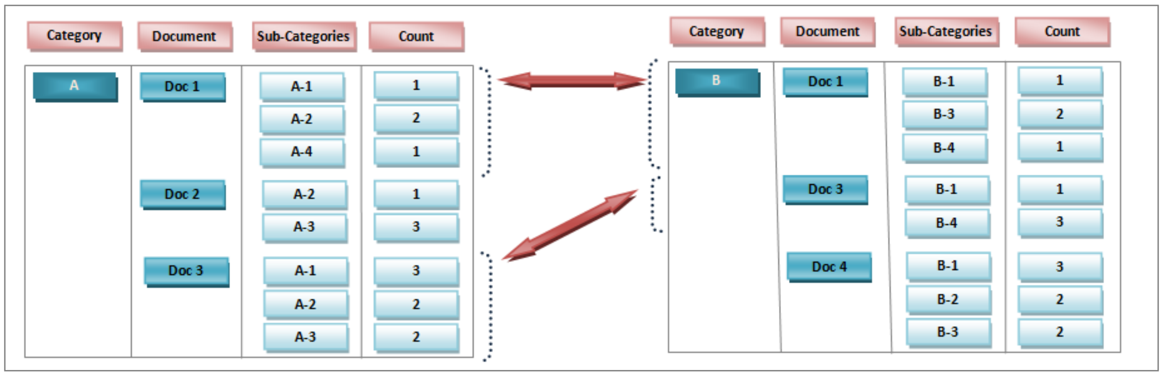
We start with an empty list and keep adding category which has the highest importance score until we have k items in the list. The list is the resulting top k analysis level categories.

3.1.5 Generating Result Charts

Step 7: Generate information associated with the two selected categories in order to produce the result matrix chart

Given the top k analysis level categories, users can select two of them to generate the matrix chart. Otherwise, by default, the top-ranked category is used as the row value and the second-ranked category is used as the column value for the matrix chart. For each of the two selected categories, we need to trace three things: the documents that contained the category, the associated sub-categories in the documents that contained the category, and the appearance frequency for the associated sub-categories in the documents that contained the category.

Figure 18 Category Information of Category A and Category B

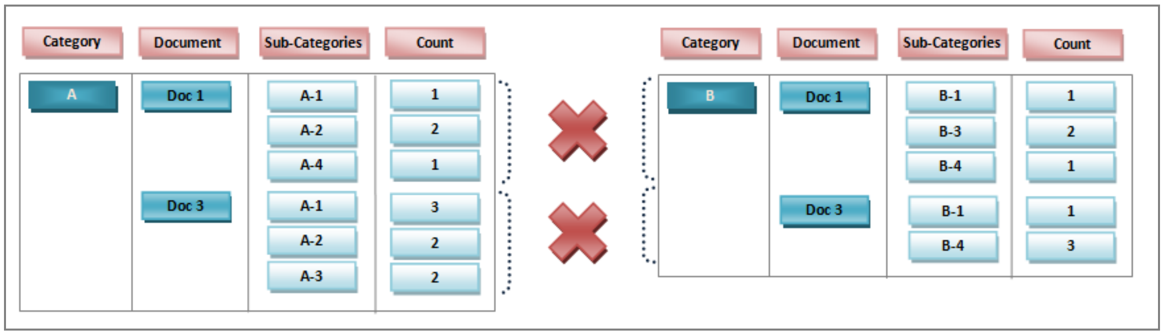


We can refer to Figure 18 to see an illustration. Suppose the two selected categories are A and B, we need to track the documents contained them. In

Figure 18, we see category A are contained by document 1, 2, and 3 while category B are contained by document 1, 3, and 4. For each document, we also track the sub-categories that appeared in it, and the associated frequencies. Refer to Figure 18, we see there are 3 sub-categories for category A in document 1, which are sub-category A-1, A-2, and A-3. The number of times that A-1 appeared in document 1 is "1", and the number of times for A-2 appeared in document 1 is "2". We refer all information associated with each category as *category information*.

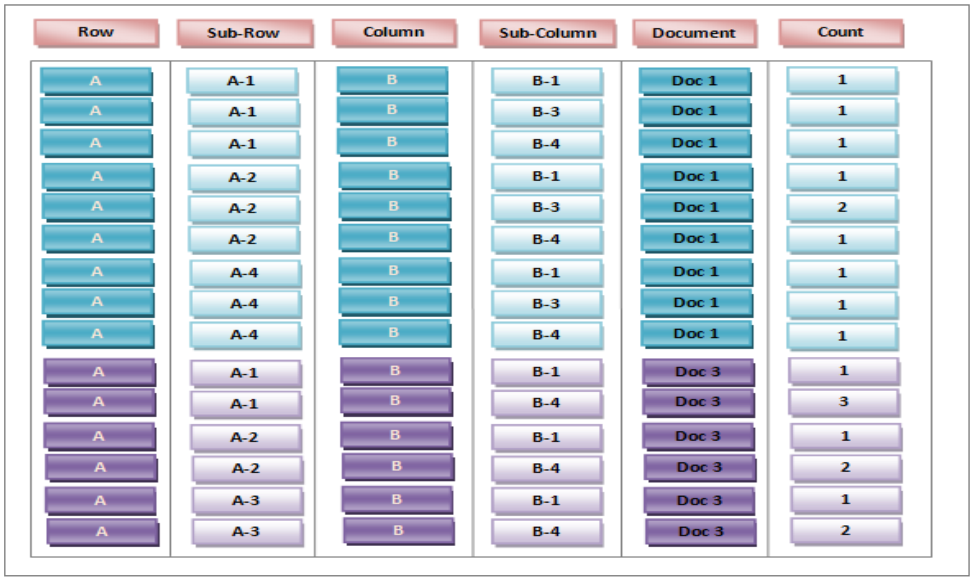
The purpose to produce *category information* for each category is to determine which sub-categories to be included in the matrix chart. Not every sub-category will show on the matrix chart. Only the sub-categories from the documents that contain both selected categories are included in the matrix chart. To illustrate by an example from Figure 18, only the sub-categories appeared in document 1 and document 3 are included in the matrix chart, since they are the only two documents that contain both category A and category B.

Figure 19 Process to Apply Cross Products



After we generate *category information*, we can produce the information required for the matrix cells. For each document that contains both selected categories, we do cross products on the associated sub-categories. Refer to Figure 19, we apply cross products on the sub-categories of category A and category B for both document 1 and document 3.

Figure 20 Example of Matrix Cell Information

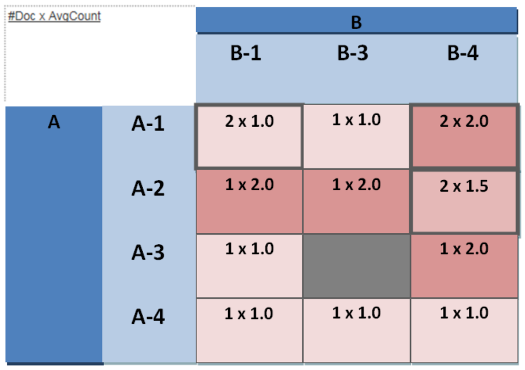


Row	Sub-Row	Column	Sub-Column	Document	Count
A	A-1	B	B-1	Doc 1	1
A	A-1	B	B-3	Doc 1	1
A	A-1	B	B-4	Doc 1	1
A	A-2	B	B-1	Doc 1	1
A	A-2	B	B-3	Doc 1	2
A	A-2	B	B-4	Doc 1	1
A	A-4	B	B-1	Doc 1	1
A	A-4	B	B-3	Doc 1	1
A	A-4	B	B-4	Doc 1	1
A	A-1	B	B-1	Doc 3	1
A	A-1	B	B-4	Doc 3	3
A	A-2	B	B-1	Doc 3	1
A	A-2	B	B-4	Doc 3	2
A	A-3	B	B-1	Doc 3	1
A	A-3	B	B-4	Doc 3	2

Figure 20 can demonstrate the result of the cross products. The *count* of the cross products is the minimum of the counts from both sub-categories. The minimum of both counts implies that we count the frequency of both sub-categories appeared together in a certain document. Refer to Figure 19, we are going to get 6 rows as the result of applying cross products on sub-categories from document 3, which are the last 6 rows in Figure 20. We refer the results of applying cross products as *matrix cell information*. The <u>categories</u> in *matrix cell information* are row and column value, and the <u>sub-categories</u> in *matrix cell* *information* are sub-row and sub-column values. The <u>document</u> and <u>count</u> are used to generate cell values.

Step 8: Generate the result matrix chart

Figure 21 Example of a Matrix Chart



#Doc x AvgCount		B		
		B-1	B-3	B-4
A	A-1	2 x 1.0	1 x 1.0	2 x 2.0
	A-2	1 x 2.0	1 x 2.0	2 x 1.5
	A-3	1 x 1.0		1 x 2.0
	A-4	1 x 1.0	1 x 1.0	1 x 1.0

After we gain the *matrix cell information*, we can employ it to produce the result matrix chart. We aggregate the matrix cell information based on “Row”, “Sub-Row”, “Column”, and “Sub-Column”. The “Document” and “Count” are used to generate the cell values in the result matrix chart. We can refer to Figure 20 to see the example of matrix cell information and refer to Figure 21 to see the example of the result matrix chart.

For each sub-row and sub-column value pair on the matrix chart, we need to compute the number of documents that contains the value pair, and calculate average count of the times that the sub-row value and sub-column value appear together in each document. The formula to compute the average count is listed below. Note that we round the average count to its first decimal digit.

$$average\ count = \frac{\text{total number of times that the sub category pair occurs}}{\text{total number of documents containing the value pair of the cell}}$$

We can refer to Figure 20 to see an example. Both the document 1 and document 3 contain the sub-row and sub-column value pair: “A-1” and “B-1”. In addition, the value pair appears once in each document. Therefore, in the result matrix chart in Figure 21, the cell value for the value pair “A-1” and “B-1” is “2x1.0”.

The border width of the cell on the matrix chart represents the number of documents contain the value pair. For example, in Figure 21, the cell with 2 documents has a thicker border than the cell with only 1 document. In addition, the background colour of the cell reflects the average score. The darker the colour is, the higher the average score is. To see an example from Figure 21, the cell with the average score “2.0” has a darker background colour than the cell with the average score “1.0” or “1.5”.

3.2 Operations in Detail

There are several operations available in our application. The list of main operations is listed and described in section 2.5. In this section, we are going to discuss the algorithm for each operation.

3.2.1 Redraw Matrix Chart

Users can select any two categories from the list of top k analysis level categories to generate a new matrix chart. The operation is implemented by performing the Step 7 and the Step 8 described in section 3.1.5, and the two selected categories are inputs for the Step 7.

3.2.2 View Article

All documents in the input collection are read into main memory in the Step 1 described in section 3.1.3. Users can select any document title, and the document content will be retrieved and displayed in the *Article Frame*.

3.2.3 Rank Article on the Selected Cell of the Matrix Chart

For each sub-row and sub-column value pair on the matrix chart, we counted the number of times that the value pair appears together in a document. We refer this count as the *contribution score*. A high *contribution score* for a document implies that the sub-row and sub-column value pair appears together in the document for many times. Therefore, the document contributes a bigger portion to the total counts of the value pair than the other documents.

In order to rank the list of documents containing the value pair, we can sort the list of document by its *contribution score* in descending order. The first ranked one is the most important document to the sub-row and sub-column value pair, while the bottom ranked one is the least important document to the value pair.

3.2.4 Drilling Operation on the Selected Cell of the Matrix Chart

Users can select a certain cell and perform the drilling down operation. Drilling down operation is to apply further analysis on documents that contain the selected sub-row and sub-column value pair.

Refer to Figure 21, we assume there are 5 documents in the input document collection initially. If the user chooses to drill down on “A-1” and “B-1” value pair, we will perform a further analysis on the 2 documents which contain the value pair. Our application will take these 2 documents and perform the steps from Step 4 to Step 8 described above. As a result, we obtain a new list of top k analysis level categories and a new matrix chart.

After users drill down on a certain cell, they can also perform the drilling up operation to retrieve the initial top k analysis level categories and the initial matrix chart.

3.2.5 Operations on Sub-Row and Sub-Column of the Matrix Chart

Users can explore the sub-row value and/or the sub-column value by increasing the category levels of the sub-row and/or sub-column. The purpose is to see how documents scatter on sub-categories with different category levels. For each sub-row or sub-column value, we can look up its less general category using the category tree we built in the Step 3 described in section 3.1.3. After we convert each sub-row or sub-column value to its less general category, we re-assign documents to cells of the matrix chart based on how they scatter on these less general categories. A new matrix chart is generated to reflect the changes.

After users explore the sub-row value and/or the sub-column value by increasing the category levels of the sub-row and/or sub-column, they can also decrease the category levels to the initial level, which is analysis level plus 1, and retrieve the initial matrix chart.

3.2.6 View Category Sub Tree

In order to give users an overall idea on the row and column category hierarchy, we provide one category sub tree chart for each category. The row and column categories are used as the roots for the category sub trees. We use the category tree we built in the Step 3 described in section 3.1.3, and look up the row and column categories. All descendants for the row category form the sub tree for the row category, and all descendants for the column category form the sub tree for the column category.

3.3 Bottlenecks and Improvements for the Baseline Solution

The baseline solution works fine when the input document collection is small. For a document collection containing less than 50 documents, our tool can generate the list of top k analysis level categories and the matrix chart within a reasonable time period. However, when the size of the input document collection is enlarged, the time required to produce results for our tool is increased dramatically.

In order to test out our application, we feed a document collection which contains 5000+ documents into our tool. It takes several hours before the results can be generated. Therefore, to achieve a better performance, we are motivated to improve the steps for each stage that we described in section 3.1. The improvements for the baseline algorithm and implementation are discussed in the following sections. After we have improved the process in each stage, we can produce results for the same document collection with 5000+ documents within 15 minutes.

3.3.1 Improving Pre-Processing

We have identified some bottlenecks in the Pre-Processing Stage, and we will discuss the improvements in this section to address those issues. The main bottleneck in the Pre-Processing Stage is related to the usage of the external tool *WordNet*. In our baseline solution, we loop through all words in the input document collection and use *WordNet* to look up the original form for each word. The look up process by using *WordNet* is slow, which takes around 0.02 second to perform one look up. This affects the performance of our tool dramatically especially when the size of the input document collection is large.

To demonstrate the effect by a real number example, assume the input document collection contains 1000 documents, and each document contains 500 words in average. Since each look up takes 0.02 second, we need 10000 seconds, which is 166 minutes, or 2.78 hours, to look up all words in the input document collection.

In addition to using *WordNet* to screen out quality words in the input document collection, we also use *WordNet* to look up hierarchy information for each quality word. The hierarchy information for each quality word is essential in order to build up the category tree. Assume half of the entire words in the input document collection are quality words, from the previous example, we need an additional 5000 seconds, or 1.39 hours in order to build up the category tree. It degrades the performance of tool seriously.

We improve the process by maintaining a list of stop words and building a local look-up table in the main memory. The list of stop words containing all common stop words in English and the look-up table tracks three things: words with some morphological changes; words in their original form; the hierarchy information of the original words. Each row in the look-up table is consisted of a pair of words and one object. The first word in the pair is the word with certain morphological change, and the second word in the pair is the first word in its original form. The object contains the hierarchy information of the word in its original form. We refer the first word as the *morph word*, and the second word as the *quality word*.

For each word in the input document collection, we check whether it is a stop word. If it is not a stop word, we search the word in the look-up table against the list of *morph words*. If the word is found, we retrieve the corresponding *quality word* without using *WordNet.* If the word cannot be found in the look-up table, we need to perform a look up using *WordNet*. If the word is a *quality word*, we insert a row which contains the word, the quality word, and the hierarchy information gained from *WordNet* into local look-up table. Otherwise, if the word is not a quality word, we insert it into the stop word list.

The advantage of using a local look-up table is to avoid performing look up using *WordNet* for repeated words. All unique words in the input document collection will be looked up using *WordNet* at most once. Since there is only a small amount of English words that are commonly used, we have saved considerable time in the look up operation, especially for a large input document collection. In addition, we have saved time to look up hierarchy information for quality words, since the information is also maintained in the local look-up table.

After we implemented the stop word list and local look-up table, we have observed dramatic improvement for an input document collection with 5000+ documents and approximately 13130 unique *quality words*. The time to screen out quality words is cut down from 8-9 hours to 4-5 minutes, and the time to build up the category tree is cut down from 4-5 hours to 1 minute.

To improve our process further, we maintain the list of stop words, the local look-up table, and the category tree in the main memory statically. The purpose is to avoid rebuilding the list of stop words, the look-up table and the category tree from scratch for a new input document collection. We do an incremental increase when we encounter a new word, which is not appeared in any of the three structures we tracked. By doing this, we save even more time on the look up operation for the second and after input document collections.

3.3.2 Improving Top K Category Generation

We have identified some bottlenecks in the Analysis Stage, and we will discuss the improvements in this section to address those issues. The main bottleneck in the Analysis Stage is due to the calculation and aggregation on a huge amount of data. In our baseline solution, we look up analysis level categories and sub-categories for each quality word in every document. Assume we have 1000 documents in the input collection and each document has an average of 300 quality words, we will have 300000 pieces of data. Assume each quality word contains 1.5 analysis level category in average, we get 450000 pieces of data after we convert all quality words into the analysis level categories.

Next, we calculate the ntf-idf on the look up result, which are the analysis level categories. In order to calculate the ntf-idf, we need to calculate each of the “tf”, “ntf”, “df”, and “idf”. Using the previous example, we will go through the 450000 pieces of data for 5 passes. Assume we can process 500 pieces of data in 1 second, we need 900 seconds in order to digest the entire 450000 pieces of data for each pass of calculation. In other words, we need 4500 seconds to manipulate the data before we get the ntf-idf results, which is 75 minutes, or 1.25 hours. In addition to that, we need to do an aggregation on the analysis level category for the huge amount of data in order to calculate the importance score, which involves one more pass of calculation on the result data.

In our improvement, we try to reduce the amount of data that we tracked also decrease the number of passes of calculation. First, we look up analysis level categories and sub-categories for the list of unique quality words instead of performing look up operation on every quality word in every document. The purpose is to avoid performing look up operation on repeated quality words and to maintain a smaller size of tracking data.

In the next step of our improvement, we start with the list of unique analysis level categories and fill in scores for each category. The advantage is to avoid manipulating large amount of data, and avoid performing the aggregation operation on the analysis level category. In the baseline solution, we calculate ntf-idf and importance score in six passes: “df”, “idf”, “”tf”, “ntf”, “ntf-idf”, and “importance score”. In our improvement, we calculate “df”, “idf”, aggregated “tf” and aggregated “ntf” at one pass, and we calculate aggregated “ntf-idf” and “importance score” together in the second pass. As a result, we cut down the total number of passes to two. The advantage is to avoid unnecessary looping through data.

Assume that one-tenth of the 300000 words are unique, then we have 30000 unique words and 45000 unique categories in total. Using the same processing speed as the previous example, we only need 90 second in a pass. Note that we also saved computing time on the aggregation operation. After we implemented the improvement, the required time is cut down from 2-3 hours to 5 minutes for an input document collection with 5000+ documents and approximately 13130 unique *quality words.*

3.3.3 Improving Result Charts Generation

We have identified some bottlenecks in the Chart Generation Stage, and we will discuss the improvements in this section to address those issues. The main bottleneck in the Chart Generation Stage is due to the manipulation on a huge amount of data. In our baseline solution, we need to aggregate the analysis level sub-categories associated with the two chosen analysis level categories. In order to achieve this, we collect all quality words that associated with the two selected analysis level categories in each document, and the analysis level sub-categories for those selected quality words in each document. After we acquire all information, we loop through each document and screen out the documents which contain both selected analysis level categories. Finally, we produce nodes for the result matrix chart using those screened out documents.

Assume the input document collection contains 1000 documents, and each document has an average of 300 quality words, we start with 300000 pieces of quality words. Further, assume one-tenth of the quality words are associated with the selected analysis level categories, and one-tenth of the documents contain both categories, we need to perform look up operations 30000 times.

In our improved process, we first gather analysis level sub-categories information and corresponding quality words for the two selected analysis level categories from the category tree. The purpose is to maintain a much smaller list in our main memory and reduce the number of look up operations. Assume each of the selected analysis level categories has 100 children, which is equivalent to 100 analysis level sub-categories, we reduce the number of look up operation from 30000 times to 200 times.

After we gather information of the analysis level sub-categories and the associated quality words, we loop through each document in the input collection. For each document, we verify whether it contains both of the selected analysis level categories. If the document contains both analysis level categories, we track the analysis level sub-categories associated with the quality words. Note that we have already maintained the list of analysis level sub-categories and the associated quality words in the main memory, so we do not need to perform category tree look up operation here. In our improvement, we only track 3000 pieces of data at the maximum. Comparing to the baseline solution, we start with 300000 pieces of quality words and cut down to 30000 pieces of data in the first round. Then, we perform 30000 look up operations and a further cut down to 3000 pieces of data at the second round.

After we implemented the improvement, the time required is reduced from 1-1.5 hours to 5 minutes for an input document collection with 5000+ documents and approximately 13130 unique quality words.

4: EMPIRICAL EVALUATION

In this chapter, we describe the dataset that we use as an input for *Docs Summarizer*. In addition, we discuss how we pre-process the dataset in order to conduct the test, and demonstrate one use case for our tool.

4.1 Dataset and Pre-processing

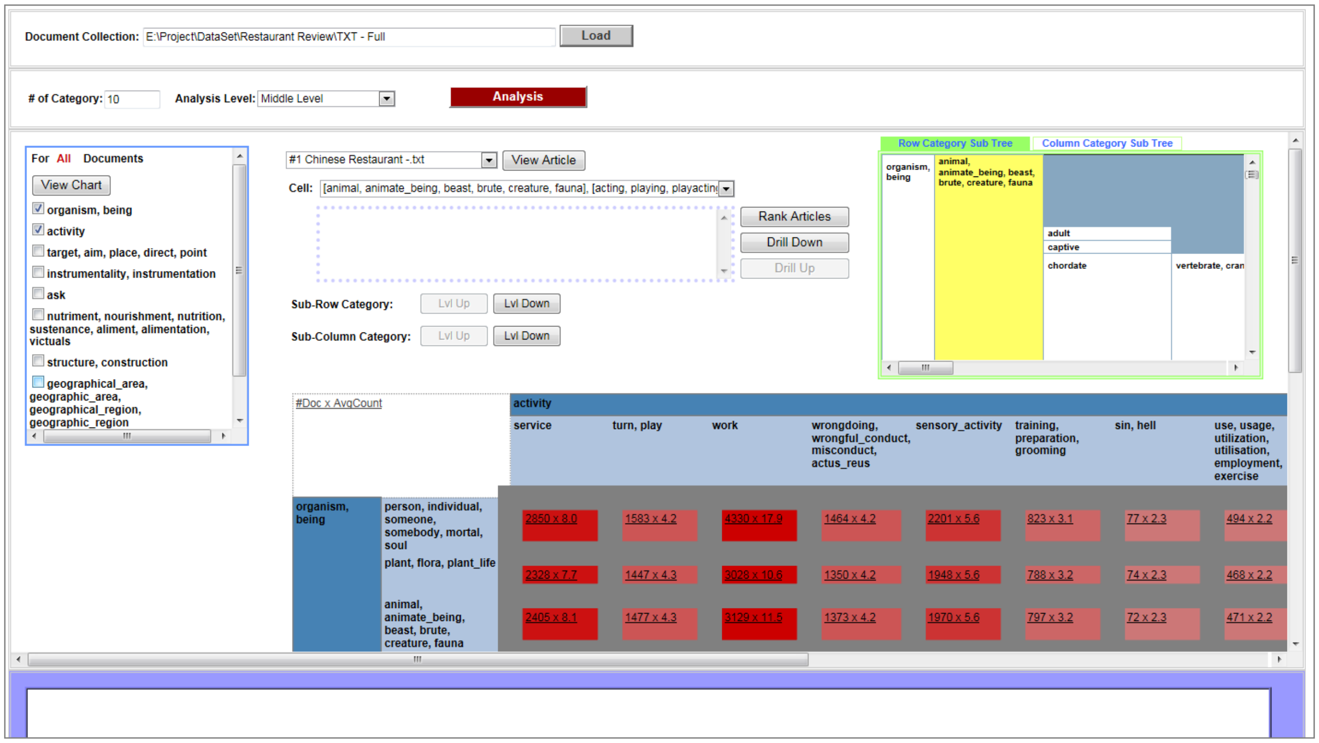
We employ the *Restaurant Review* Dataset to conduct experiments on our application. The *Restaurant Review* Dataset is a bunch of XML files, where each file represents one single restaurant and is assigned an index as the file name. In each file, it contains basic information of the restaurant, such as the restaurant name, price range, operation hours, etc. In addition, it contains a collection of reviews and rating from different sources. In the *Restaurant Review* Dataset, there are 5531 XML files in this collection with a total size of 45.1 MB.

In order to conduct tests on the dataset, we need to perform some pre-processing. First, we want to convert each XML file to a text file format. We rename each file by the name of the restaurant it represents, instead of using a random index number as the file name. Next, we only want to include files that contain reviews, since our goal is to analyze reviews for different restaurants using our tool. Last, we fill each new text file by treating each review in the XML file as one paragraph. As a result, we get 5305 text files with a total size of 22 MB.

To summarize the result of using the pre-processed *Restaurant Review* Dataset as the input document collection for our tool, we generate the final matrix chart in 15 minutes. The timeline breakdown is approximately 5 minutes for each of the three stages: the Pre-Processing Stage, the Analysis Stage, and the Chart Generation Stage. In the Step 2 of the Pre-Processing Stage, we process approximately 1000 documents per minute, and there are 13130 unique quality words in total from the input collection.

4.2 Case Study: Avoid the Least Popular Restaurants in Town

Figure 22 Analysis Results for Using the *Restaurant Review* Dataset as Input


Document Collection: E:\Project\DataSet\Restaurant Review\TXT - Full

# of Category: 10 Analysis Level: Middle Level

For All Documents

- [✓] organism, being
- [✓] activity
- [ ] target, aim, place, direct, point
- [ ] instrumentality, instrumentation
- [ ] ask
- [ ] nutriment, nourishment, nutrition, sustenance, aliment, alimentation, victuals
- [ ] structure, construction
- [ ] geographical_area, geographic_area, geographical_region, geographic_region

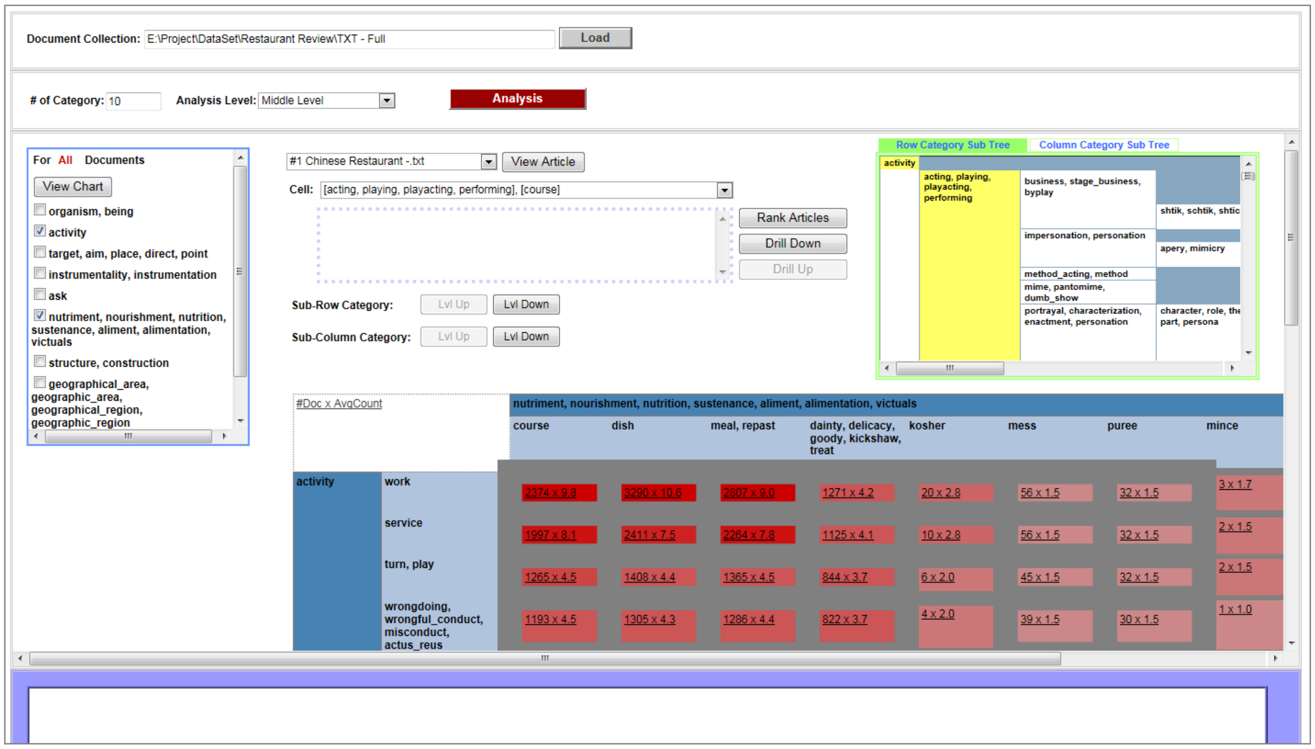
#1 Chinese Restaurant -.txt

Cell: [animal, animate_being, beast, brute, creature, fauna], [acting, playing, playacting

#Doc x AvgCount		activity							
		service	turn, play	work	wrongdoing, wrongful_conduct, misconduct, actus_reus	sensory_activity	training, preparation, grooming	sin, hell	use, usage, utilization, utilisation, employment, exercise
organism, being	person, individual, someone, somebody, mortal, soul	2850 x 8.0	1583 x 4.2	4330 x 17.9	1464 x 4.2	2201 x 5.6	823 x 3.1	77 x 2.3	494 x 2.2
	plant, flora, plant_life	2328 x 7.7	1447 x 4.3	3028 x 10.6	1350 x 4.2	1948 x 5.6	788 x 3.2	74 x 2.3	468 x 2.2
	animal, animate_being, beast, brute, creature, fauna	2405 x 8.1	1477 x 4.3	3129 x 11.5	1373 x 4.2	1970 x 5.6	797 x 3.2	72 x 2.3	471 x 2.2

Assume that we have an important date, and we want to use our tool to find out the least popular restaurants and avoid going to any of them. We use the *Restaurant Review* Dataset as the input document collection of our tool, and the analysis results are demonstrated in Figure 22. The analysis results include a list of top 10 categories and a matrix chart which has the top two categories as its row and column values. We can use the operation buttons in our tool to perform further explorations.

Figure 23 Matrix Chart for Users-Selected Categories


Document Collection: E:\Project\DataSet\Restaurant Review\TXT - Full

# of Category: 10 Analysis Level: Middle Level

For All Documents

- [ ] organism, being
- [✓] activity
- [ ] target, aim, place, direct, point
- [ ] instrumentality, instrumentation
- [ ] ask
- [✓] nutriment, nourishment, nutrition, sustenance, aliment, alimentation, victuals
- [ ] structure, construction
- [ ] geographical_area, geographic_area, geographical_region, geographic_region

#1 Chinese Restaurant -.txt

Cell: [acting, playing, playacting, performing], [course]

Sub-Row Category:

Sub-Column Category:

Row Category Sub Tree | Column Category Sub Tree

activity			
	acting, playing, playacting, performing	business, stage_business, byplay	
			shtik, schtik, shtic
		impersonation, personation	
			apery, mimicry
		method_acting, method	
		mime, pantomime, dumb_show	
		portrayal, characterization, enactment, personation	character, role, the part, persona

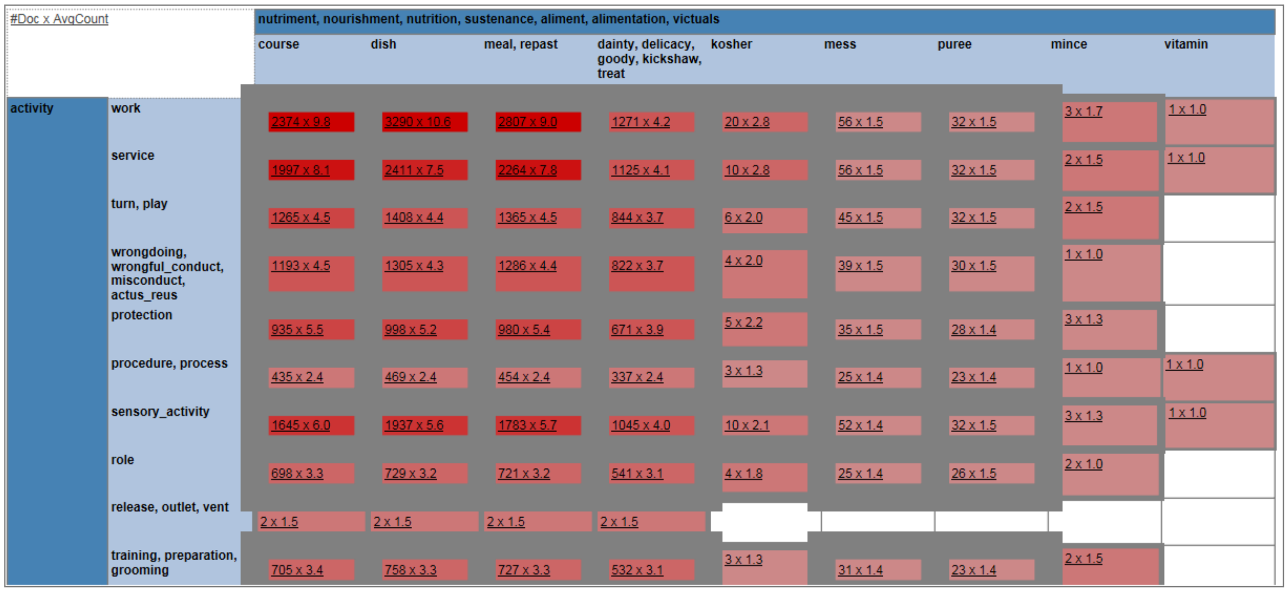
#Doc x AvgCount		nutriment, nourishment, nutrition, sustenance, aliment, alimentation, victuals							
		course	dish	meal, repast	dainty, delicacy, goody, kickshaw, treat	kosher	mess	puree	mince
activity	work	2374 x 9.8	3290 x 10.6	2807 x 9.0	1271 x 4.2	20 x 2.8	56 x 1.5	32 x 1.5	3 x 1.7
	service	1997 x 8.1	2411 x 7.5	2264 x 7.8	1125 x 4.1	10 x 2.8	56 x 1.5	32 x 1.5	2 x 1.5
	turn, play	1265 x 4.5	1408 x 4.4	1365 x 4.5	844 x 3.7	6 x 2.0	45 x 1.5	32 x 1.5	2 x 1.5
	wrongdoing, wrongful_conduct, misconduct, actus_reus	1193 x 4.5	1305 x 4.3	1286 x 4.4	822 x 3.7	4 x 2.0	39 x 1.5	30 x 1.5	1 x 1.0

We may define a least popular restaurant as providing bad food or poor services. Therefore, we can explore more on the categories “activity” and "nutriment, nourishment, nutrition, sustenance, aliment, alimentation, victuals". We can redraw the matrix chart for the two selected categories, and the new chart is displayed in Figure 23.

Refer to the matrix chart in Figure 23, we gain information of how the review documents scatter on the different sub-columns and sub-rows at a glance.

We can focus on the matrix cells which have darker background colour and thicker borders. Most reviews that covered the two selected categories are

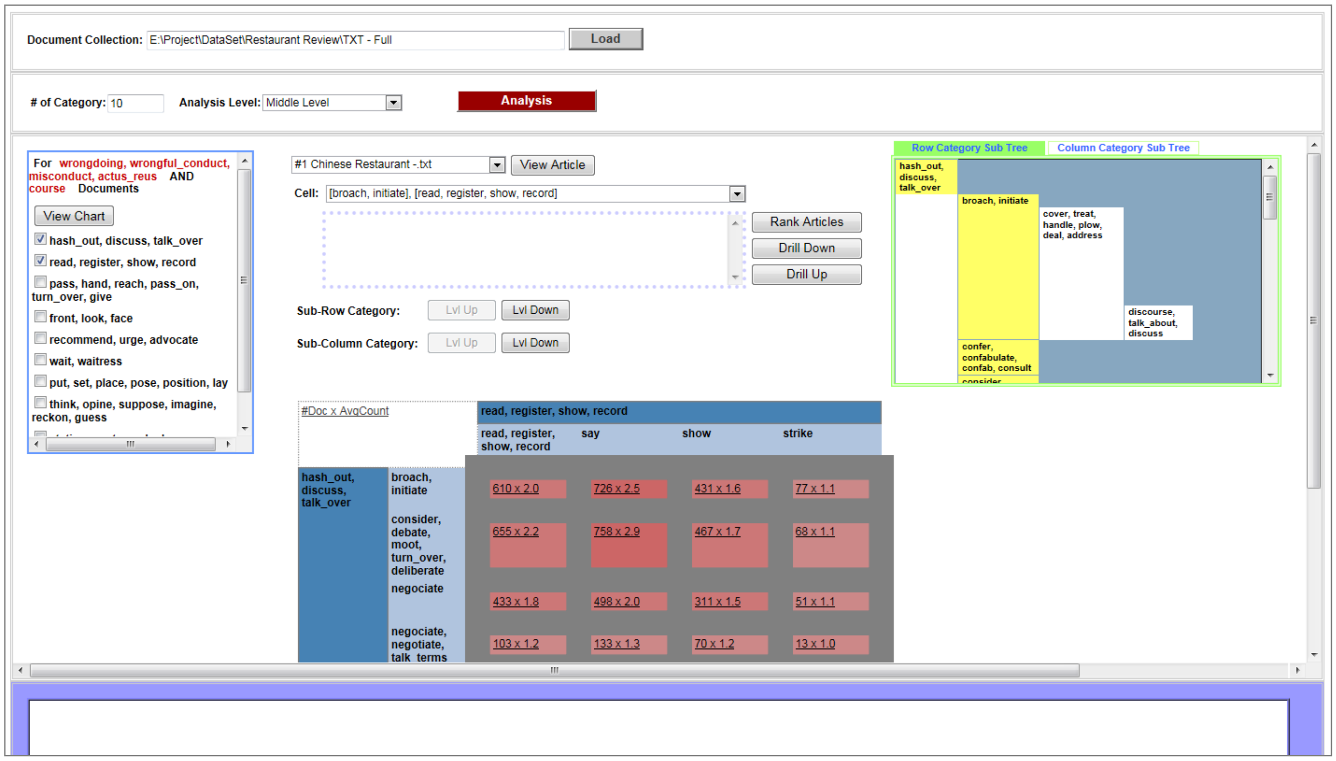
Figure 24 Part of the Enlarged Matrix Chart for Users-Selected Categories



#Doc x AvgCount		nutriment, nourishment, nutrition, sustenance, aliment, alimentation, victuals								
		course	dish	meal, repast	dainty, delicacy, goody, kickshaw, treat	kosher	mess	puree	mince	vitamin
activity	work	2374 x 9.8	3290 x 10.6	2807 x 9.0	1271 x 4.2	20 x 2.8	56 x 1.5	32 x 1.5	3 x 1.7	1 x 1.0
	service	1997 x 8.1	2411 x 7.5	2264 x 7.8	1125 x 4.1	10 x 2.8	56 x 1.5	32 x 1.5	2 x 1.5	1 x 1.0
	turn, play	1265 x 4.5	1408 x 4.4	1365 x 4.5	844 x 3.7	6 x 2.0	45 x 1.5	32 x 1.5	2 x 1.5	
	wrongdoing, wrongful_conduct, misconduct, actus_reus	1193 x 4.5	1305 x 4.3	1286 x 4.4	822 x 3.7	4 x 2.0	39 x 1.5	30 x 1.5	1 x 1.0	
	protection	935 x 5.5	998 x 5.2	980 x 5.4	671 x 3.9	5 x 2.2	35 x 1.5	28 x 1.4	3 x 1.3	
	procedure, process	435 x 2.4	469 x 2.4	454 x 2.4	337 x 2.4	3 x 1.3	25 x 1.4	23 x 1.4	1 x 1.0	1 x 1.0
	sensory_activity	1645 x 6.0	1937 x 5.6	1783 x 5.7	1045 x 4.0	10 x 2.1	52 x 1.4	32 x 1.5	3 x 1.3	1 x 1.0
	role	698 x 3.3	729 x 3.2	721 x 3.2	541 x 3.1	4 x 1.8	25 x 1.4	26 x 1.5	2 x 1.0	
	release, outlet, vent	2 x 1.5	2 x 1.5	2 x 1.5	2 x 1.5					
	training, preparation, grooming	705 x 3.4	758 x 3.3	727 x 3.3	532 x 3.1	3 x 1.3	31 x 1.4	23 x 1.4	2 x 1.5	

related to service, dishes, and meals. We can refer to Figure 24 to see the enlarged matrix chart and find interesting sub-row and sub-column value pairs to do further exploration. Since we want to find restaurants with bad reputations, we select the cell with the value pair ("wrong doing, wrongful conduct, misconduct", "course") to perform drill down operation. The new analysis results after we drill down on the selected cell are shown in Figure 25.

Figure 25 New Analysis Results for Documents Related to "Wrong doing, wrongful conduct, misconduct" And "Course"



Document Collection: E:\Project\DataSet\Restaurant Review\TXT - Full

# of Category: 10 Analysis Level: Middle Level

For wrongdoing, wrongful_conduct, misconduct, actus_reus AND course Documents

- [✓] hash_out, discuss, talk_over
- [✓] read, register, show, record
- [ ] pass, hand, reach, pass_on, turn_over, give
- [ ] front, look, face
- [ ] recommend, urge, advocate
- [ ] wait, waitress
- [ ] put, set, place, pose, position, lay
- [ ] think, opine, suppose, imagine, reckon, guess

#1 Chinese Restaurant -.txt

Cell: [broach, initiate], [read, register, show, record]

Sub-Row Category:

Sub-Column Category:

#Doc x AvgCount		read, register, show, record			
		read, register, show, record	say	show	strike
hash_out, discuss, talk_over	broach, initiate	610 x 2.0	726 x 2.5	431 x 1.6	77 x 1.1
	consider, debate, moot, turn_over, deliberate	655 x 2.2	758 x 2.9	467 x 1.7	68 x 1.1
	negociate	433 x 1.8	498 x 2.0	311 x 1.5	51 x 1.1
	negociate, negotiate, talk_terms	103 x 1.2	133 x 1.3	70 x 1.2	13 x 1.0

hash_out, discuss, talk_over

broach, initiate

cover, treat, handle, plow, deal, address

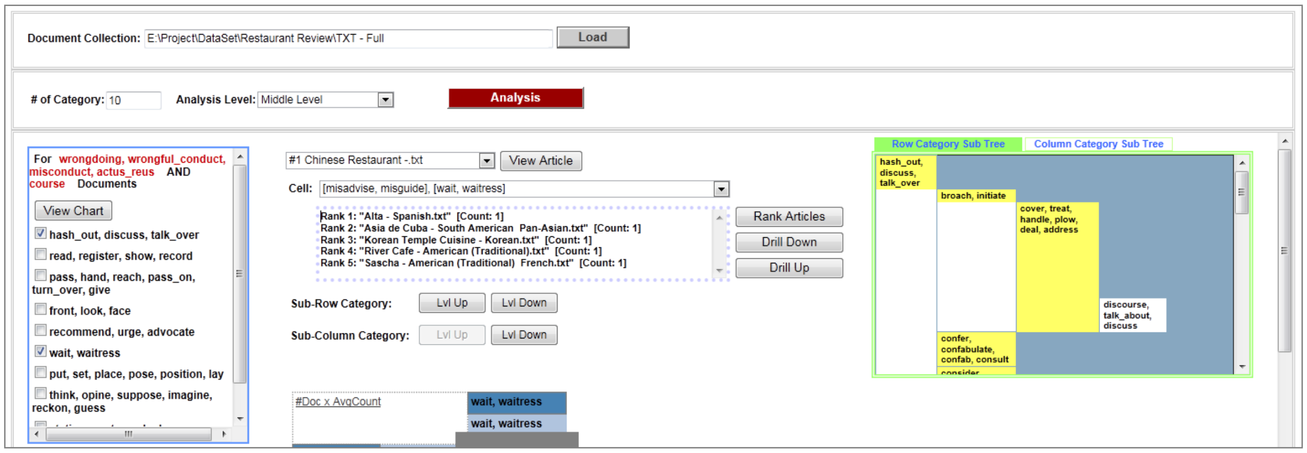
discourse, talk_about, discuss

confer, confabulate, confab, consult

consider

For all review documents related to "wrong doing, wrongful conduct, misconduct" and "course", we get a new list of top 10 categories and the new matrix chart, which are displayed in Figure 25. We want to explore more on how servers might behave wrongly by talking wrongly to customers, and therefore we choose "hash out, discuss, talk over" and "wait, waitress" categories. Using the two selected categories, we generate a new matrix chart.

Figure 26 New Analysis Results of "Hash out, discuss, talk over" and "Wait, waitress" Categories for Documents Related to "Wrong doing, wrongful conduct, misconduct" And "Course"



Document Collection: E:\Project\DataSet\Restaurant Review\TXT - Full

# of Category: 10 Analysis Level: Middle Level

For wrongdoing, wrongful_conduct, misconduct, actus_reus AND course Documents

- [✓] hash_out, discuss, talk_over
- [ ] read, register, show, record
- [ ] pass, hand, reach, pass_on, turn_over, give
- [ ] front, look, face
- [ ] recommend, urge, advocate
- [✓] wait, waitress
- [ ] put, set, place, pose, position, lay
- [ ] think, opine, suppose, imagine, reckon, guess

#1 Chinese Restaurant -.txt

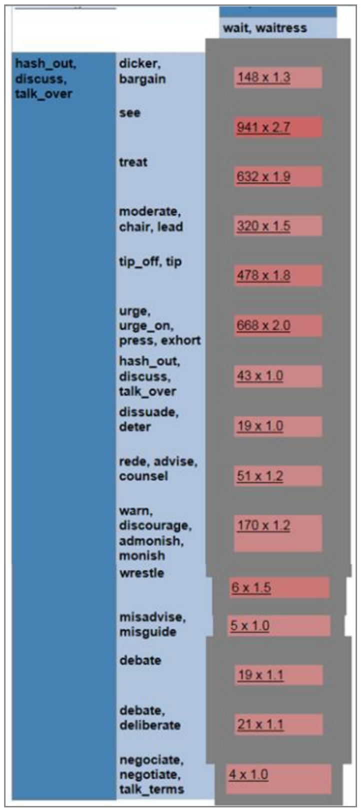
Cell: [misadvise, misguide], [wait, waitress]

```
Rank 1: "Alta - Spanish.txt"  [Count: 1]
Rank 2: "Asia de Cuba - South American  Pan-Asian.txt"  [Count: 1]
Rank 3: "Korean Temple Cuisine - Korean.txt"  [Count: 1]
Rank 4: "River Cafe - American (Traditional).txt"  [Count: 1]
Rank 5: "Sascha - American (Traditional)  French.txt"  [Count: 1]
```

Sub-Row Category:

Sub-Column Category:

Figure 27 New Matrix Chart of "Hash out, discuss, talk over" and "Wait, waitress" Categories for Documents Related to "Wrong doing, wrongful conduct, misconduct" And "Course"

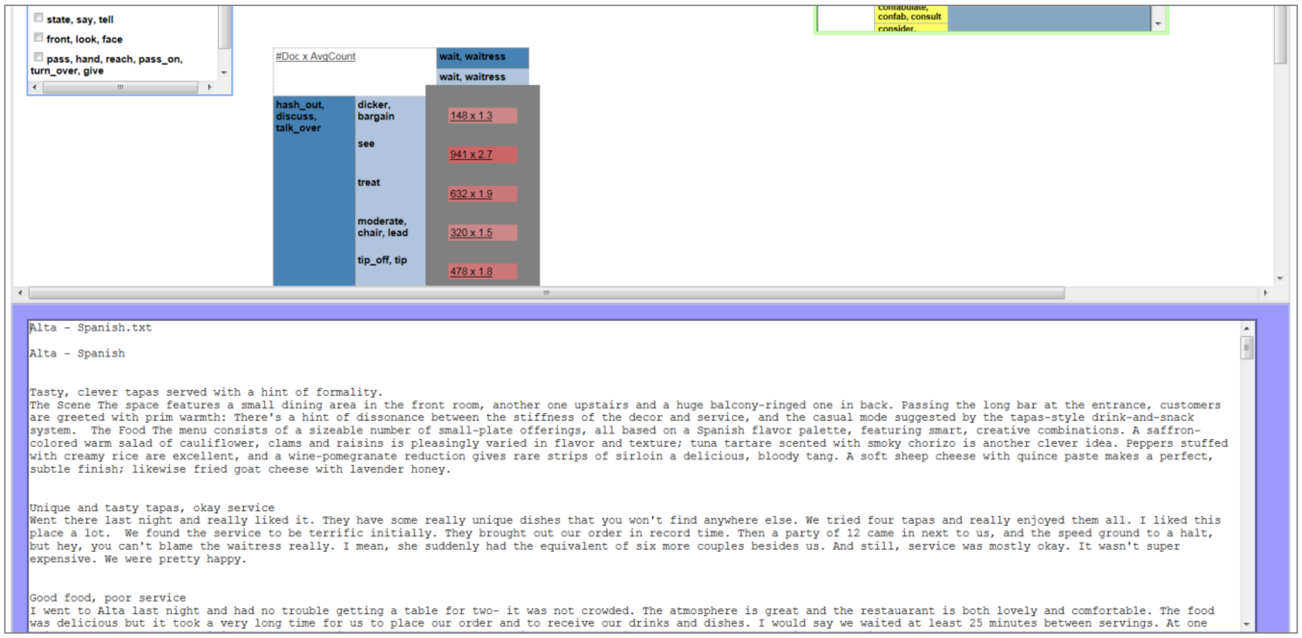


		wait, waitress
hash_out, discuss, talk_over	dicker, bargain	148 x 1.3
	see	941 x 2.7
	treat	632 x 1.9
	moderate, chair, lead	320 x 1.5
	tip_off, tip	478 x 1.8
	urge, urge_on, press, exhort	668 x 2.0
	hash_out, discuss, talk_over	43 x 1.0
	dissuade, deter	19 x 1.0
	rede, advise, counsel	51 x 1.2
	warn, discourage, admonish, monish	170 x 1.2
	wrestle	6 x 1.5
	misadvise, misguide	5 x 1.0
	debate	19 x 1.1
	debate, deliberate	21 x 1.1
	negociate, negotiate, talk_terms	4 x 1.0

The new analysis results are displayed in Figure 26. We observe the row category sub-tree, and adjust the sub-row category in the matrix chart to the category level that we have interests. The newly enlarged matrix chart is displayed in Figure 27.

From the matrix chart, we can choose cells that we are interested in, and rank the review documents by their contributions to the selected cell. We choose the cell with the value pair (“misadvise, misguide”, “wait, waitress”) from the drop down box in Figure 26, and we get a list of five documents related to “misadvise, misguide” and “wait, waitress”.

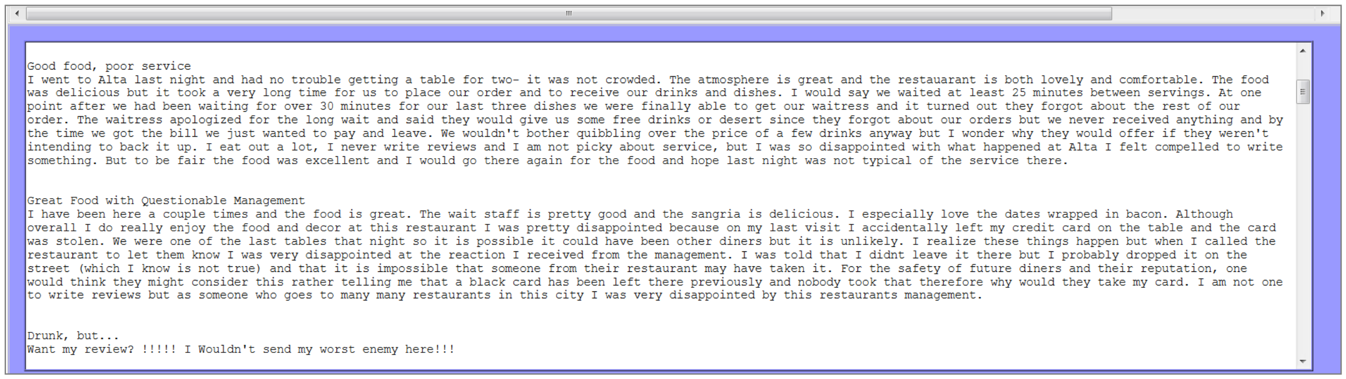
Figure 28 Chosen Article: “Alta – Spanish.txt”



```
Alta - Spanish.txt

Alta - Spanish


Tasty, clever tapas served with a hint of formality.
The Scene The space features a small dining area in the front room, another one upstairs and a huge balcony-ringed one in back. Passing the long bar at the entrance, customers
are greeted with prim warmth: There's a hint of dissonance between the stiffness of the decor and service, and the casual mode suggested by the tapas-style drink-and-snack
system.  The Food The menu consists of a sizeable number of small-plate offerings, all based on a Spanish flavor palette, featuring smart, creative combinations. A saffron-
colored warm salad of cauliflower, clams and raisins is pleasingly varied in flavor and texture; tuna tartare scented with smoky chorizo is another clever idea. Peppers stuffed
with creamy rice are excellent, and a wine-pomegranate reduction gives rare strips of sirloin a delicious, bloody tang. A soft sheep cheese with quince paste makes a perfect,
subtle finish; likewise fried goat cheese with lavender honey.


Unique and tasty tapas, okay service
Went there last night and really liked it. They have some really unique dishes that you won't find anywhere else. We tried four tapas and really enjoyed them all. I liked this
place a lot.  We found the service to be terrific initially. They brought out our order in record time. Then a party of 12 came in next to us, and the speed ground to a halt,
but hey, you can't blame the waitress really. I mean, she suddenly had the equivalent of six more couples besides us. And still, service was mostly okay. It wasn't super
expensive. We were pretty happy.


Good food, poor service
I went to Alta last night and had no trouble getting a table for two- it was not crowded. The atmosphere is great and the restauarant is both lovely and comfortable. The food
was delicious but it took a very long time for us to place our order and to receive our drinks and dishes. I would say we waited at least 25 minutes between servings. At one
```

We can choose articles from the ranking list to read, and get more insights. The chosen article is displayed in the Article Panel. We can refer to Figure 28 to read the content of the chosen article, “Alta – Spanish.txt”. By reading the comments in the article, we see there are many negative comments complaining about poor services, although the food quality is good in overall. We can refer to Figure 29 to see an example of the comments. Both of the two comments are pointing out the food is tasty, but the service quality is low.

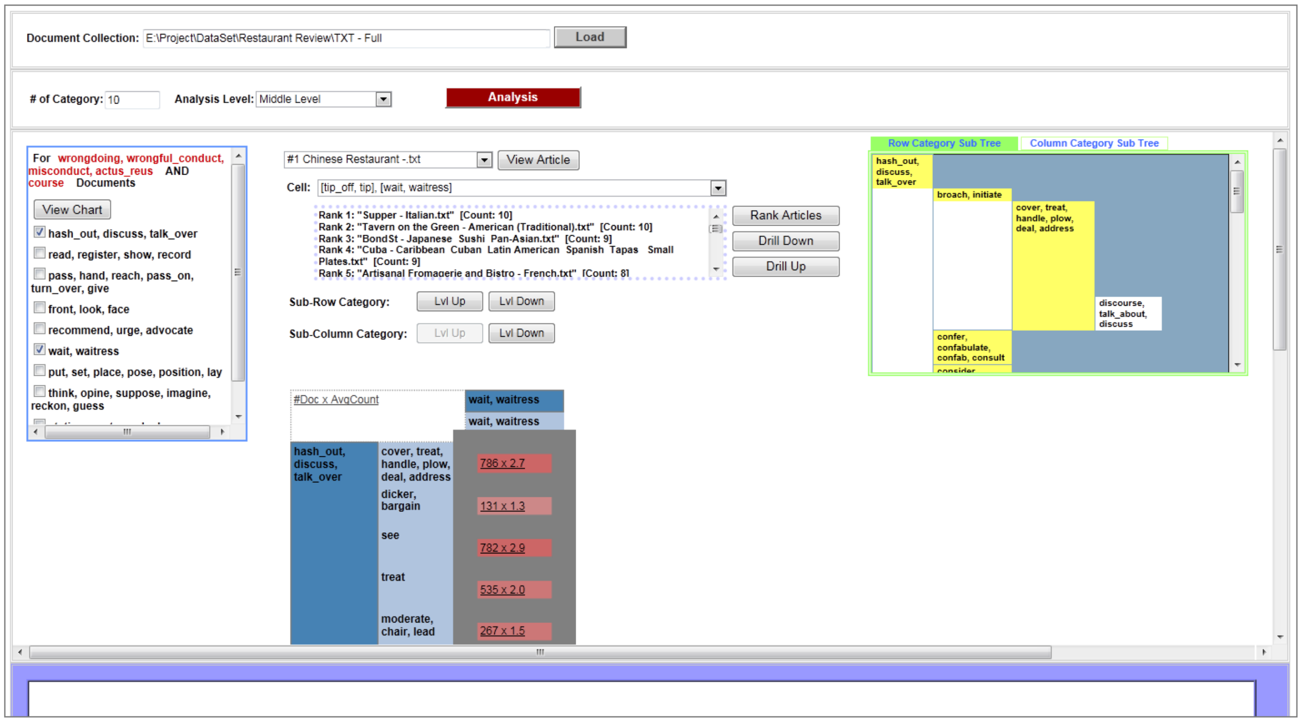
Figure 29 Related Comments from the Chosen Article: "Alta – Spanish.txt"



```
Good food, poor service
I went to Alta last night and had no trouble getting a table for two- it was not crowded. The atmosphere is great and the restauarant is both lovely and comfortable. The food
was delicious but it took a very long time for us to place our order and to receive our drinks and dishes. I would say we waited at least 25 minutes between servings. At one
point after we had been waiting for over 30 minutes for our last three dishes we were finally able to get our waitress and it turned out they forgot about the rest of our
order. The waitress apologized for the long wait and said they would give us some free drinks or desert since they forgot about our orders but we never received anything and by
the time we got the bill we just wanted to pay and leave. We wouldn't bother quibbling over the price of a few drinks anyway but I wonder why they would offer if they weren't
intending to back it up. I eat out a lot, I never write reviews and I am not picky about service, but I was so disappointed with what happened at Alta I felt compelled to write
something. But to be fair the food was excellent and I would go there again for the food and hope last night was not typical of the service there.


Great Food with Questionable Management
I have been here a couple times and the food is great. The wait staff is pretty good and the sangria is delicious. I especially love the dates wrapped in bacon. Although
overall I do really enjoy the food and decor at this restaurant I was pretty disappointed because on my last visit I accidentally left my credit card on the table and the card
was stolen. We were one of the last tables that night so it is possible it could have been other diners but it is unlikely. I realize these things happen but when I called the
restaurant to let them know I was very disappointed at the reaction I received from the management. I was told that I didnt leave it there but I probably dropped it on the
street (which I know is not true) and that it is impossible that someone from their restaurant may have taken it. For the safety of future diners and their reputation, one
would think they might consider this rather telling me that a black card has been left there previously and nobody took that therefore why would they take my card. I am not one
to write reviews but as someone who goes to many many restaurants in this city I was very disappointed by this restaurants management.


Drunk, but...
Want my review? !!!!! I Wouldn't send my worst enemy here!!!
```

For more exploration, we can choose another cell that we are interested in. To investigate how restaurants build up the bad reputations by asking unreasonable tips while providing poor service, we choose cell with the value pair of "tip off, tip" and "wait, waitress". We can view the list of articles ranked by their contributions to the chosen cell.

Figure 30 List of Ranked Articles for Cell with Value Pair of "Tip off, tip" And "Wait, Waitress"



Document Collection: E:\Project\DataSet\Restaurant Review\TXT - Full

# of Category: 10 Analysis Level: Middle Level

For wrongdoing, wrongful_conduct, misconduct, actus_reus AND course Documents

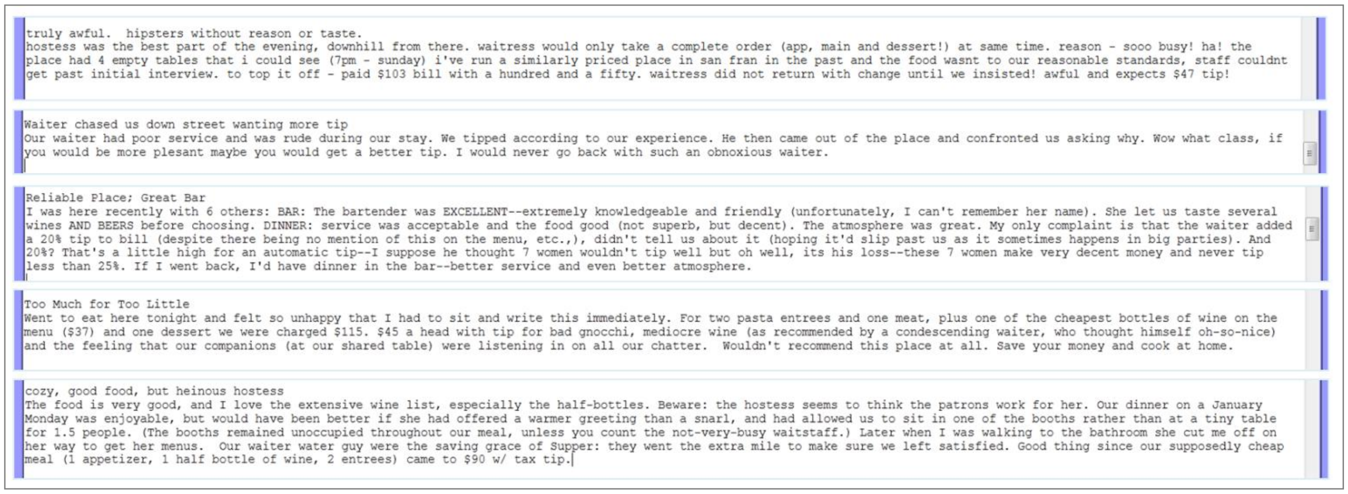
☑ hash_out, discuss, talk_over
☐ read, register, show, record
☐ pass, hand, reach, pass_on, turn_over, give
☐ front, look, face
☐ recommend, urge, advocate
☑ wait, waitress
☐ put, set, place, pose, position, lay
☐ think, opine, suppose, imagine, reckon, guess

#1 Chinese Restaurant -.txt

Cell: [tip_off, tip], [wait, waitress]

Rank 1: "Supper - Italian.txt" [Count: 10]
Rank 2: "Tavern on the Green - American (Traditional).txt" [Count: 10]
Rank 3: "BondSt - Japanese Sushi Pan-Asian.txt" [Count: 9]
Rank 4: "Cuba - Caribbean Cuban Latin American Spanish Tapas Small Plates.txt" [Count: 9]
Rank 5: "Artisanal Fromagerie and Bistro - French.txt" [Count: 8]

Figure 31 Some Example of Articles



```
truly awful.  hipsters without reason or taste.
hostess was the best part of the evening, downhill from there. waitress would only take a complete order (app, main and dessert!) at same time. reason - sooo busy! ha! the
place had 4 empty tables that i could see (7pm - sunday) i've run a similarly priced place in san fran in the past and the food wasnt to our reasonable standards, staff couldnt
get past initial interview. to top it off - paid $103 bill with a hundred and a fifty. waitress did not return with change until we insisted! awful and expects $47 tip!

Waiter chased us down street wanting more tip
Our waiter had poor service and was rude during our stay. We tipped according to our experience. He then came out of the place and confronted us asking why. Wow what class, if
you would be more plesant maybe you would get a better tip. I would never go back with such an obnoxious waiter.

Reliable Place; Great Bar
I was here recently with 6 others: BAR: The bartender was EXCELLENT--extremely knowledgeable and friendly (unfortunately, I can't remember her name). She let us taste several
wines AND BEERS before choosing. DINNER: service was acceptable and the food good (not superb, but decent). The atmosphere was great. My only complaint is that the waiter added
a 20% tip to bill (despite there being no mention of this on the menu, etc.,), didn't tell us about it (hoping it'd slip past us as it sometimes happens in big parties). And
20%? That's a little high for an automatic tip--I suppose he thought 7 women wouldn't tip well but oh well, its his loss--these 7 women make very decent money and never tip
less than 25%. If I went back, I'd have dinner in the bar--better service and even better atmosphere.

Too Much for Too Little
Went to eat here tonight and felt so unhappy that I had to sit and write this immediately. For two pasta entrees and one meat, plus one of the cheapest bottles of wine on the
menu ($37) and one dessert we were charged $115. $45 a head with tip for bad gnocchi, mediocre wine (as recommended by a condescending waiter, who thought himself oh-so-nice)
and the feeling that our companions (at our shared table) were listening in on all our chatter.  Wouldn't recommend this place at all. Save your money and cook at home.

cozy, good food, but heinous hostess
The food is very good, and I love the extensive wine list, especially the half-bottles. Beware: the hostess seems to think the patrons work for her. Our dinner on a January
Monday was enjoyable, but would have been better if she had offered a warmer greeting than a snarl, and had allowed us to sit in one of the booths rather than at a tiny table
for 1.5 people. (The booths remained unoccupied throughout our meal, unless you count the not-very-busy waitstaff.) Later when I was walking to the bathroom she cut me off on
her way to get her menus.  Our waiter water guy were the saving grace of Supper: they went the extra mile to make sure we left satisfied. Good thing since our supposedly cheap
meal (1 appetizer, 1 half bottle of wine, 2 entrees) came to $90 w/ tax tip.
```

We can refer to Figure 30 to see the list of ranked articles. Reading the comments presented in the list of documents, we find most of the comments are related to bad service and attitude while the restaurants charge customer an unreasonable amount of tips. Some of the example comments from the list of documents are displayed in Figure 31.

We can do further exploration using our tool. As a result, we can avoid the restaurants with bad services and dishes by referring to the comments provided by previous customers. Therefore, we can prevent from picking a wrong restaurant and ruin the important date.

5: CONCLUSIONS AND FUTURE WORK

5.1 Summary of the Project

The purpose of our tool *Docs Summarizer* is to automate the process of summarizing a collection of documents, and get an overall picture of the topics covered by the document collection. The summarized results are easy to understand with simple visualization. In addition to that, users are able to get more details on selected topics by performing various operations.

Our Tool can take a collection of documents as input, and apply analysis on them to generate a series of meaningful outputs. The outputs include a list of top k analysis level categories where the analysis level is an input from users. One of the other output is a two-dimensional matrix chart, where each dimension represents one analysis level category selected from the top k list. The users can do further exploration on the top k analysis level categories or the matrix chart by performing operations, such as drilling down on one matrix cell.

To conclude, in many occasions, we see there is a strong need for a text summarization tool, which can summarize a collection of text documents and help users to save their time on filtering out interesting articles. Users can only focus on useful articles and conduct further analysis by using our tool.

5.2 Future Work

Although we have improved several things for our tool (please refer to Chapter 3.3 for more details), those major main improvements are aiming for speeding up our tool by making our process more efficient. In fact, there are many other areas possible to be addressed in the future. In this section, we list out some of the future works and improvements to make the application more practical and more robust.

- Allow users to input several collections of documents to our tool at the same time for analysis
- Allow users to input links for blog located at the internet to our tool for analysis
- Allow users to output analysis results which may be displayed independently or use as input of the other tool
- Allow users to save analysis results and retrieve them later
- Generate multiple dimensional result matrix charts
- Save intermediate results and employ the results to speed up future analysis

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