INFORMATION ANALYTICS AND ACCESSIBILITY FOR THE VISUALLY IMPAIRED

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Introduction

Information explosion over the internet.
World Wide Web (WWW) and Screen-Based Devices

• WWW has become a powerful Internet tool that allows users to access various types of resources since its invention.

• It presents information in a variety of formats such as images, animations, sound samples, or movies.

• WWW has become pervasive in education and workforce development.
Is Web for all?

• BUT – most of this information access occurs on screen-based devices and is designed as visual information

• Persons with disabilities such as individuals with hearing impairments, visual impairments, and learning disabilities etc., may encounter great difficulties to access the information from the Web or other screen-based devices.

• Many governments and international organizations stated that the accessibility to services and information on the web is a fundamental right for any citizens.
Information Access through the Aural World

• Sounds from various sources can be captured.

• Sequences of the sounds can be formed to explain concepts in a manner which is more effective and importantly FUN!

• Concepts can be broken down into individual component and sounds developed for each concept can be played as a short sequence called “audeme”.

An example of a concatenated string of concepts as Audemes depicting the process of Soil Erosion
What are Audemes?

- Short sound collages, approximately 4-8 seconds, of sound effects (SFX).
- Audemes are either micro-narratives or metaphors of the target concept.
- Audemes can be used to represent concepts: e.g. the sounds of thunder + lightning crash + rain drumming to make an audeme signifying “THUNDERSTORM.”
- Audemes can use sounds that are “examples and evidence” of the target concept: E.g. cow moos + chicken clucks + horse whinny + pig grunts to signify “FARM ANIMALS.”
- Audemes can also use metaphoric, emotionally appropriate or indirectly related sounds to suggest or evoke the concept: E.g. sleigh bells jingling and a slowly descending bell cascade to signify “SNOW.” (Add a howling wind and a distant scream to suggest “BLIZZARD.”)
- **Could Audemes can be used for information Accessibility?**
Audeme-based Learning, Memory, and Recall – Studies at the Indiana School for the Blind and Visually Impaired (ISBVI)

After Two Weeks

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Gain (Posttest - Pretest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-0.17</td>
</tr>
<tr>
<td>Encode</td>
<td>1</td>
</tr>
<tr>
<td>Encode+Recall</td>
<td>2.20</td>
</tr>
<tr>
<td>Radio</td>
<td>1.60</td>
</tr>
<tr>
<td>US Constitution</td>
<td>0.83</td>
</tr>
<tr>
<td>Slavery</td>
<td>2.17</td>
</tr>
</tbody>
</table>

Radio: Slavery
...and even after five months.
Automating the Audeme Generation Process

• Challenges
  • What do words/concepts sound like?
    • Simple examples:
      • What is the sound of thunder?
      • What is the sound of radio?
    • Complicated example:
      • How to describe soil erosion, or osmosis?
      • How to explain photosynthesis?
      • What is the sound of day?
Content Mapping using Natural Language Processing
Content Mapping Pipeline
Text Summarization

• Research on text summarization was started quite in the early of 1950’s by Luhn.

• Summarizing the text will allow us to convey the same information content with minimum number of sentences which best describes the original concept.
Text Summarization – LSI

- Latent Semantic Indexing (LSI) means analyzing documents to find the underlying/latent meaning/semantics or concepts of those documents.

- The fundamental difficulty in finding relevant documents from search words is that what we really want is to compare the meanings or concepts behind the words.

- LSI attempts to solve this problem by mapping both words and documents into a "concept" space and doing the comparison in this space.
Text Summarization using LSI

- Latent semantic Indexing (LSI) is a technique for extracting the hidden dimensions of the semantic representation of terms, sentences, or documents, on the basis of their contextual use.
- The first step is the creation of a term by sentences matrix $A$.
- The next step is to apply Singular Value Decomposition (SVD) to matrix $A$. 

![Diagram of SVD](image)
Example: Contour plowing reduces the downhill flow of water. Soil Loss: Fertile topsoil is important to plant growth. New topsoil takes hundreds or thousands of years to form. The Explore Activity at the beginning of this chapter shows that rain washes away loose topsoil. Wind also blows it away. The movement of soil from one place to another is called erosion. Eroded soil that washes into a river or stream can block sunlight and slow photosynthesis. It also can harm fish, clams, and other organisms. Erosion is a natural process, but human activities increase it. When a farmer plows a field or a forest is cut down, soil is left bare. Bare soil is more easily carried away by rain and wind. Figure 19 shows some methods farmers use to reduce soil erosion.

Summarized text:
- Soil Loss Fertile topsoil is important to plant growth.
- The movement of soil from one place to another is called erosion.
- Eroded soil that washes into a river or stream can block sunlight and slow photosynthesis.
- Bare soil is more easily carried away by rain and wind.
- Figure 19 shows some methods farmers use to reduce soil erosion.
Content Mapping Pipeline

1. Textbook material
2. Paragraphs
3. Text Summarization
4. Actor Identification using CRF
5. Dependency Analysis on actors
6. Production chain construction
7. Actor mapping to select Audemes
Actor Identification

Actor identification or signal detection is a technique used to detect a presence “key” information in a textual material. The key information identified can be used to build a dictionary that can be used for analysis.

Example: Contour plowing reduces the downhill flow of water. Soil Loss: Fertile topsoil is important to plant growth. New topsoil takes hundreds or thousands of years to form. The Explore Activity at the beginning of this chapter shows that rain washes away loose topsoil. Wind also blows it away. The movement of soil from one place to another is called erosion. Eroded soil that washes into a river or stream can block sunlight and slow photosynthesis. It also can harm fish, clams, and other organisms. Erosion is a natural process, but human activities increase it. When a farmer plows a field or a forest is cut down, soil is left bare. Bare soil is more easily carried away by rain and wind. Figure 19 shows some methods farmers use to reduce soil erosion.
CRF : Training process

- Sentence is converted into the format in Table 2. The “START” and “END” are padded to show the beginning and ending of the sentence.
- The CRF model trains on the features and previous words of the “Actor” words for making predictions.

<table>
<thead>
<tr>
<th>Sentence</th>
<th>POS</th>
<th>SP</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>The</td>
<td>DT</td>
<td>B-NP</td>
<td>O</td>
</tr>
<tr>
<td>trough</td>
<td>NN</td>
<td>E-NP</td>
<td>Actor</td>
</tr>
<tr>
<td>is</td>
<td>VBZ</td>
<td>S-VP</td>
<td>O</td>
</tr>
<tr>
<td>the</td>
<td>DT</td>
<td>B-NP</td>
<td>O</td>
</tr>
<tr>
<td>lowest</td>
<td>JJS</td>
<td>I-NP</td>
<td>Actor</td>
</tr>
<tr>
<td>point</td>
<td>NN</td>
<td>E-NP</td>
<td>Actor</td>
</tr>
<tr>
<td>of</td>
<td>IN</td>
<td>S-PP</td>
<td>O</td>
</tr>
<tr>
<td>the</td>
<td>DT</td>
<td>B-NP</td>
<td>O</td>
</tr>
<tr>
<td>wave</td>
<td>NN</td>
<td>E-NP</td>
<td>Actor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t</th>
<th>Yt</th>
<th>Xt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O</td>
<td>((START), The, trough)</td>
</tr>
<tr>
<td>2</td>
<td>Actor</td>
<td>(The, trough, is)</td>
</tr>
<tr>
<td>3</td>
<td>O</td>
<td>(trough, is, the)</td>
</tr>
<tr>
<td>4</td>
<td>O</td>
<td>(is, the, lowest)</td>
</tr>
<tr>
<td>5</td>
<td>Actor</td>
<td>(the, lowest, point)</td>
</tr>
<tr>
<td>6</td>
<td>Actor</td>
<td>(lowest, point, of)</td>
</tr>
<tr>
<td>7</td>
<td>O</td>
<td>(point, of, the)</td>
</tr>
<tr>
<td>8</td>
<td>O</td>
<td>(of, the, wave)</td>
</tr>
<tr>
<td>9</td>
<td>Actor</td>
<td>(the, wave, .)</td>
</tr>
<tr>
<td>10</td>
<td>O</td>
<td>(wave, ., (END))</td>
</tr>
</tbody>
</table>
CRF Training and Testing

- The training set consists of sentences along with the features such as the POS tags, Shallow parser tags and labels are assigned to keywords.
- A trained model is created by CRF using which is then used on the test set for keyword identification.
- The test set contains sentences and only the features.

Training Set with features and label

Test sentence to predict label

<table>
<thead>
<tr>
<th>Sentence</th>
<th>POS</th>
<th>SP</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>NN</td>
<td>B-NP</td>
<td></td>
</tr>
<tr>
<td>Loss</td>
<td>NN</td>
<td>I-NP</td>
<td></td>
</tr>
<tr>
<td>Fertile</td>
<td>JJ</td>
<td>I-NP</td>
<td></td>
</tr>
<tr>
<td>topsoil</td>
<td>NN</td>
<td>E-NP</td>
<td></td>
</tr>
<tr>
<td>is</td>
<td>VBZ</td>
<td>S-VP</td>
<td></td>
</tr>
<tr>
<td>important</td>
<td>JJ</td>
<td>S-ADJP</td>
<td></td>
</tr>
<tr>
<td>to</td>
<td>TO</td>
<td>S-PP</td>
<td></td>
</tr>
<tr>
<td>plant</td>
<td>NN</td>
<td>B-NP</td>
<td></td>
</tr>
<tr>
<td>growth</td>
<td>NN</td>
<td>E-NP</td>
<td></td>
</tr>
</tbody>
</table>

Predicted Labels

Actor
Actor
Actor
Actor
O
O
O
Actor
Actor
O
Actor Identification using CRF - Example

Soil Loss: Fertile topsoil is important to plant growth.

The movement of soil from one place to another is called erosion.

Eroded soil that washes into a river or stream can block sunlight and slow photosynthesis.

Bare soil is more easily carried away by rain and wind.

Figure 19 shows some methods farmers use to reduce soil erosion.
Content Mapping Pipeline

- Textbook material
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- Actor mapping to select Audemes
Dependency Analysis

- The dependency parser provides a representation of semantic relation relationship between words in a sentence. It provides an effective means to identify concept term relations.

Soil Loss: Fertile topsoil is important to plant growth.

<table>
<thead>
<tr>
<th>Typed dependencies, collapsed view</th>
<th>Typed dependencies view</th>
</tr>
</thead>
<tbody>
<tr>
<td>amod(Loss-2, Soil-1)</td>
<td>amod(Loss-2, Soil-1)</td>
</tr>
<tr>
<td>root(ROOT-0, Loss-2)</td>
<td>root(ROOT-0, Loss-2)</td>
</tr>
<tr>
<td>nn(topsoil-5, Fertile-4) nsubj(important-7, topsoil-5) xsubj(plant-9, topsoil-5)</td>
<td>nn(topsoil-5, Fertile-4) nsubj(important-7, topsoil-5) xsubj(plant-9, topsoil-5)</td>
</tr>
<tr>
<td>cop(important-7, is-6)</td>
<td>cop(important-7, is-6)</td>
</tr>
<tr>
<td>dep(Loss-2, important-7)</td>
<td>dep(Loss-2, important-7)</td>
</tr>
<tr>
<td>aux(plant-9, to-8)</td>
<td>aux(plant-9, to-8)</td>
</tr>
<tr>
<td>xcomp(important-7, plant-9)</td>
<td>xcomp(important-7, plant-9)</td>
</tr>
<tr>
<td>dobj(plant-9, growth-10)</td>
<td>dobj(plant-9, growth-10)</td>
</tr>
</tbody>
</table>
Dependency Analysis using Dependency Parsers

The movement of soil from one place to another is called erosion.
Dependency Analysis - Groupings

- Soil, Loss, Fertile, topsoil, plant, growth
- movement, Soil, erosion
- soil, washes, river, stream
- block, Sunlight, slow, photosynthesis
- Bare, soil, more, carried, rain, wind
- methods, farmers, reduce, soil, erosion
Content Mapping Pipeline

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A production chain is a representation of a step-by-step process that is taken in order to build a concept. It shows the transformation of raw objects into completed concepts.
Production Chain Construction for Sentences

- Once the groupings from the Dependency Parser is done, each group is arranged into an hierarchical fashion and a production chain is constructed.
- A production chain view helps in understanding the various factors that affect a certain concept.
Content Mapping Pipeline

1. Textbook material
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3. Text Summarization
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6. Production chain construction
7. Audeme Selection
Audeme Selection

- Each Audeme is tagged with a set of words by the expert.
- These words show what the Audeme consist of.

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Audeme Name</th>
<th>Audeme Tags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>A_Earth_1</td>
<td>- element, dirt, land, terrain, territory, soil, earth science.</td>
</tr>
<tr>
<td></td>
<td>A_Earth_2</td>
<td>- earth, stone, land, ground, rock, soil.</td>
</tr>
<tr>
<td>Movement</td>
<td>A_Move_1</td>
<td>- racing, acceleration, velocity, movement.</td>
</tr>
<tr>
<td></td>
<td>A_Move_2</td>
<td>- movement, move, moving, displace, relocate, run, drive, travel.</td>
</tr>
<tr>
<td></td>
<td>A_Move_3</td>
<td>- movement, earth, sand, sediment, earth science.</td>
</tr>
<tr>
<td>Erosion</td>
<td>A_Erosion_1</td>
<td>- erosion, sandpaper, friction, particles, sediment.</td>
</tr>
<tr>
<td></td>
<td>A_Erosion_2</td>
<td>- weathering, water, erosion, ticking, time, temporal.</td>
</tr>
<tr>
<td>Wind</td>
<td>A_Wind_1</td>
<td>- micronarrative, sand, wind, sediment, desert, big.</td>
</tr>
<tr>
<td></td>
<td>A_Wind_2</td>
<td>- animal, rise up, wind, fly.</td>
</tr>
<tr>
<td></td>
<td>A_Wind_3</td>
<td>- big, sand, storm, weather, wind, desert, earth science.</td>
</tr>
<tr>
<td>Rain</td>
<td>A_Rain_1</td>
<td>- ocean, sea, water, rain, precipitation, earth science</td>
</tr>
<tr>
<td></td>
<td>A_Rain_2</td>
<td>- rain, storm, downpour, precipitation</td>
</tr>
<tr>
<td></td>
<td>A_Rain_3</td>
<td>- snow, rain, precipitation, sunny, wind, rock, geology, earth science</td>
</tr>
</tbody>
</table>
Finally, the Audemes

A_Earth_1  A_Move_1  A_Erosion_1  A_Wind_1  A_Rain_1

A_Earth_2  A_Move_2  A_Erosion_2  A_Wind_2  A_Rain_2

A_Earth_2  A_Move_3  A_Erosion_2  A_Wind_3  A_Rain_3

A_Earth_1  A_Move_3  A_Erosion_2  A_Wind_1  A_Rain_3
Experts version of Soil Erosion
Conclusions

• Audeme-based content representation for learning could be a valuable supplement to screen readers even to Braille
• Our preliminary studies with BVI children showed improved retention and recall of concepts
• Learning process is carried out using a “game-like” environment that allows BVI people to be more engaged with the emerging technologies
• The Audeme –based approach may reduce the information accessibility gap among BVI
• Much work is still needed
Acknowledgements

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Thank You!