Evaluating a Text-to-Scene Generation System as an Aid to Literacy

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Abstract

We discuss classroom experiments using WordsEye, a system for automatically generating 3D scenes from English textual descriptions. Input is syntactically and semantically processed to identify a set of graphical objects and constraints which are then rendered as a 3D scene. We describe experiments with the system in a summer literacy enrichment program conducted at the Harlem Educational Activities Fund with 6th grade students, in which students using the system had significantly greater improvement in their literary character and story descriptions in pre- and post- test essays compared with a control. Students reported that using the system helped them imagine the events in the stories they were reading better. We also observed that social interaction engendered by this process was a strong motivator.
Index Terms: text-to-scene generation

1 Introduction

Rendering complex 3D images normally requires special training and expertise – especially images that convey realistic human emotion. WordsEye [1] is a software system that converts text input into a 3D scene without requiring any kind of technical knowledge from the user. We tested our current version of WordsEye in a Harlem-based summer enrichment program for 6th grade students, who used the system in an English literature class. Before the class began, students provided a writing sample. Over the course of five weeks, students were asked to re-create scenes from Aesop's *Fables* and George Orwell's *Animal Farm* in WordsEye. They then provided a new writing sample at the end of the summer program. We found that students who used WordsEye showed significantly higher improvement on written essays than students who took the same course without WordsEye.

2 Previous Literature

The connections between visual perception and language acquisition have been a major focus of researchers in the fields of cognition, psychology, and neuroscience. Barbara Landau [2], for example, presented subjects with a block on a box and told them "the block is *acorp* the box." Subjects interpreted *acorp* to mean *on*. In contrast, when shown a stick on a box, subjects interpreted *acorp* as *across*. These results, and those of many other similar experiments, highlight well-documented theories of cognitive development by Piaget [3]: people form mental schema, or models, to assimilate the knowledge they already have and accommodate new information presented to them. Gardner [4] identified the importance of visual-spatial "intelligence," furthering the body of research linking visual perception to other important human activities, including language acquisition. Despite this research and base of knowledge, schools in the United States have placed a much larger emphasis on language acquisition than visual perception. Perceptual psychologist and art theorist Rudolf Arnheim [5] demonstrated that the dismissal of perception, and subsequently of the visual, has resulted in widespread visual illiteracy.

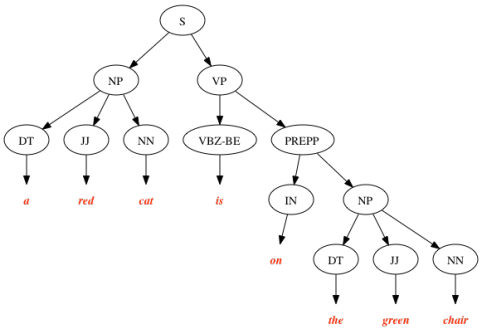
Over the past two decades, many educational researchers have focused on the connections between visual literacy and conventional literacy – that is, reading and writing. For example, there is extensive scholarship in this area in relation to a very common artifact: children's picture books. Picture books wed written text and visual imagery in a natural and cohesive manner. Lawrence Sipe [6], a researcher of children's literature, thoroughly examined the interplay between words and pictures in a picture book. Sipe described a text-picture synergy that produces an effect greater than that which text or pictures would create on their own. He cited the work of numerous scholars who attempted to depict the relationships between text and imagery in a picture book, ranging from the idea that pictures extend the text [7] to the concept that pictures and text limit each other [8]. Sipe concluded, "As readers/viewers, we are always interpreting the words in terms of the pictures and the pictures in terms of the words…The best and most fruitful readings of picture books are never straightforwardly linear, but rather involve a lot of reading, turning to previous pages, reviewing, slowing down, and reinterpreting" (p. 27).

Sipe's connections between visual imagery and written text in children's books primarily relate to the discipline of reading. Research in the realm of comic books in education further this connection to the discipline of writing. Frey and Fisher [9] presented a series of chapters dedicated to this subject, highlighting the possibilities for writing development through visual imagery. Bitz [10] demonstrated the power of student-generated comic books for writing development through a national program called the Comic Book Project. Similar outcomes for both reading and writing have been demonstrated through other visual media, including videogames [11]; film [12]; and website development [13].

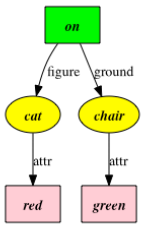
3 The WordsEye Text-to-Scene System

WordsEye is a web-based application that generates 3D scenes from text typed by a user into a browser. Scenes are generated as follows: Input sentences are parsed into a phrase structure representation using a hand-constructed grammar with feature unification to enforce subject-verb agreement and other syntactic and semantic constraints. The parse tree is then automatically converted to a dependency structure where individual words are represented by nodes, and arcs between nodes represent the syntactic relation between the words. This conversion is facilitated by the grammar that designates a head component for each production rule. Dependency structures

(a) Parse tree



(b) Dependency graph



(c) 3D representation

Figure 1: Three stages of processing for *A red cat is on the green chair.*

Dependency structures are then processed to resolve anaphora and other co-references. Syntactic dependencies are converted to semantic relations using frame-semantic roles [14] which, in turn, are converted to a final set of graphical objects and relations representing the position, orientation, size, color, texture, and poses of objects in the scene. The graphical objects themselves are automatically selected from a library of 2,200 3D objects and 10,000 images (used as textures). The library objects are tagged with spatially-relevant regions used to resolve spatial relations (for example, the area of a chair where someone would sit). The 3D scene itself can now be automatically generated by applying these graphical constraints to the selected 3D objects. The scene is rendered in OpenGL (http://www.opengl.org) and displayed in the user's browser as a jpeg image. Users can manually adjust the viewpoint, causing the server to quickly redraw the scene from a new angle and update the image. A user is free to modify text as often as they like to add more objects, fix mistakes, or specify different spatial relations. Once the user is satisfied with a scene, the system will optionally create a higher-quality final rendering with reflections and shadows by ray-tracing their scene in Radiance (http://radsite.lbl.gov/radiance). Users can post their final renderings to an online gallery where they can give it a title and post comments on each other's pictures.

The face library was built using the FaceGen 3D graphics package (http://www.facegen.com), which allows for high-level control of facial features based on statistical modeling. This software provides overall facial controls like Age and Gender, as well as highly specific Shape, Color, and Asymmetry controls, and various facial Morphs that apply emotion to the face. With this software, we were able to incorporate FaceGen capabilities into the WordsEye system, allowing users to choose faces of well-known people and add particular emotions to these characters. The system currently supports the 6 "basic" emotions: sadness, happiness, fear, anger, surprise, and disgust. Emotion words from WordNet and a thesaurus were gathered and divided into three degrees (high, medium, low), depending on their Activation scores from Whissell's Dictionary of Affect in Language [15]. These words were then associated with particular FaceGen parameters and added to WordsEye as keywords.

One major challenge faced by our system is handling the ambiguity and vagueness of language. 3D scenes require all objects and spatial relations to be explicitly defined. As a result, only the most literal language can be directly translated to graphics. For example, if the user were to type *The boy fed the cat*, the system would not know the location, the size and color of the cat, what the boy was wearing, what sort of food he fed it, and so on. We are currently working on addressing some of these issues by developing a resource of lexical and real-world knowledge useful in providing default locations and poses to help resolve underspecified or vague text. In our educational testing, these limitations forced the students to adapt their descriptions to what the system can handle. Several students reported that they enjoyed the problem solving aspects of translating their ideas into concrete and explicit language. One related challenge for the system is providing appropriate feedback in cases when the input cannot be processed, whether because of spelling or grammatical mistakes or because of limitations in the system itself. One example is that missing objects and misspelled words are handled by simply inserting extruded 3D text of the word into the scene, giving the student immediate visual feedback.

4 Classroom Testing

We performed preliminary testing of the system in schools in Virginia. After seeing WordsEye at the Innovate 2007 Exposition (hosted by the Virginia Department of Education), K-12 public school teachers from Albemarle County asked to use it in their classes as a tool for ESL remediation, special education, vocabulary enhancement, writing at all levels, technology integration, and art. Feedback from teachers and students was quite positive. In one school with a 10% ESL population, a teacher used it with 5th-6th graders to reinforce specificity of detail in descriptive writing, noting that students are "very eager to use the program and came up with some great pictures." Another teacher tested it with 6th-8th grade students "in a special language class because of their limited reading and writing ability," most reading and writing on a 2nd-3rd grade level. The students found the software fun to use, an important element in motivating learning. As one teacher reported, "One kid who never likes anything we do had a great time yesterday...was laughing out loud."

To test the hypothesis that WordsEye could serve as an effective alternative literacy tool, we designed a controlled experiment for middle school children enrolled in a summer enrichment program run by the Harlem Educational Activities Fund (HEAF). In the trial, twenty seven emerging 6th grade students in a HEAF literature course were given a writing pre-test. 41% of the students were female and 59% were male; 89% were African American, 4% were Native American, and 7% were other ethnicities. Half of the students (control) were randomly chosen to participate in a conventional literature course (i.e., group discussions and thematic analysis); the other half (treatment) were introduced to WordsEye and shown how to use it to construct pictures from text. The

control curriculum was determined and implemented by HEAF without interference from the researchers. It consisted of a variety of activities ranging from book discussion groups to the development of an original puppet show. There was some technology integrated into a number of those activities, consisting of word processing, Internet searches, and visual design software (Adobe Photoshop). The control and treatment groups spent the same amount of time on their activities. Over the next 5 weeks, the WordsEye group used WordsEye for 90 minutes a week to create scenes from the literature they read, including Aesop's fables and *Animal Farm*.

Figure 2: HEAF Student-created scene from *Animal Farm, "Pigs and farmers playing cards".*

We developed a curriculum (See Appendix) that helped instructors integrate WordsEye into the learning goals of the summer academy. The WordsEye group was also introduced to WordsEye's face manipulation capabilities, which allowed them to include their own and other well-known people's faces in scenes, and to modify the expressions of these faces by specifying particular emotions. For the rest of the course, the WordsEye group participated in the same type of class discussions and writing exercises as the control group. At the end of the course, all of the students wrote essays based on the literature they had read; pre- and post-course essays were scored by independent, trained raters. The criteria were: a) Organization and Structure b) Written Expression c) Quality and Depth of Reflection d) Use of Vocabulary e) Mechanics: Grammar, Punctuation, Spelling. Each category was judged on a scale of 1 (poor) to 5 (excellent). The average pre-test treatment score was 15.8; the average pre-test control score was 18.0. We determined that this was as close to a baseline measurement as possible, given the parameters of the summer program. The raters met to review the evaluation rubric and then independently judge two writing samples. The scores were discussed among the group, and inter-rater reliability was determined sufficient at 92%. The WordsEye group showed significantly greater improvement than for control group (Table 1). Note that, as this study was a straightforward comparison between the growth scores of two independent and randomly assigned groups with a small sample size, the researchers used a two-sample t-Test to determine statistical significance: Difference = mu (1) - mu (2); Estimate for difference: 4.81; 95% CI for difference: (0.08, 9.54); t-Test of difference = 0 (vs not =): t-Value = 2.16 p-Value = 0.047 DF = 16. As one of the students said "When you read a book, you don't get any pictures. WordsEye helps you create your own pictures, so you can picture in your mind what happens in the story."

	Pre-test	Post-test	Growth
WordsEye Group	15.82	23.17	7.35
Control group	18.05	20.59	2.54

Table 1: Evaluation of student essays

5 Discussion and Future Research

We have demonstrated that Text-to-Scene generation can provide a useful approach to literacy skills training through a formal field experiment. In future work we will enhance features of WordsEye, including integrating face manipulation into the program; adding a capability to infer appropriate emotions from input text more robustly; and extending the system to identify spelling and grammatical errors. We are also developing a set of self-contained instructional modules to allow/test distance learning in future pilots with remote school systems. We also want to explore educational settings where English is a second language for most students.

6 Appendix: WordsEye Pilot Curriculum

Session 1: ***Introduction of the Platform***

a. Introduction:

- Give students the same sentence starter:
  The dog is on the _____ .
- Change image selection of dog.
- Change color of dog.
- Change size of dog with descriptors (large, huge, tiny) and numbers (10 feet tall).
- Change color of the sky.
- Change texture of the ground.
- Add something on top of the dog.
- Add something below the dog.
- Render the final image.
- View scene in My Portfolio and the Gallery

b. Scene re-creation:

- Give students the following scene and see who can recreate it most accurately:

http://www.cs.columbia.edu/~coyne/images/clowns.jpg
(*the floor has a wood texture. the first clown is on the floor. the second clown is on the floor. the first clown is facing the second clown. the second clown is facing the first clown. there is a very large brick wall behind the floor. A large whiteboard is on the wall. the whiteboard is two feet above the floor.*)

c. Literary exploration:

- Have students re-create a scene from one of Aesop's fables, including characters, backgrounds, and anything else important to understanding the scene in depth.

Session 2: Working with Fables

a. Introduction:

- Have students open their scene for: *The dog is on the…*
- Change the point-of-view with the camera angles.
- Zoom in or out with the camera angles.
- Change the texture of the ground.
- Import an image and add it to the scene.
- Render the final scene.
- Use 2D effects to add another visual element to the scene.
- View scene in My Portfolio and the Gallery

b. Warm-up:

- Provide students with the following text from Aesop's fables. Put students in teams, one for each sentence. Ask them to recreate their assigned sentence in WordsEye so that the entire fable is recreated at the end of the activity:

"A monkey perched upon a lofty tree saw some Fishermen casting their nets into a river, and narrowly watched their proceedings. 2) The Fishermen after a while gave up fishing, and on going home to dinner left their nets upon the bank. 3) The Monkey, who is the most imitative of animals, descended from the treetop and endeavored to do as they had done. 4)

Having handled the net, he threw it into the river, but became tangled in the meshes and drowned. With his last breath he said to himself, `I am rightly served; for what business had I who had never handled a net try and catch fish?'"

c. Literary Exploration:

- Have students use WordsEye to re-create their original fables in 2 to 4 scenes. Students can transform each sentence of their fable into a scene or combine a number of different ideas into a scene. The scenes should have enough detail for others to interpret what's happening.
- Save each scene in My Portfolio, and then turn the scenes into a Picturebook using the Picturebook editor.
- Ask students to volunteer to present their scenes. See if other students can discern the moral of the fable from the scenes and presentation.

Session 3: Animal Farm Study (Part 1)

a. Warm-up:

- Give students the following *Animal Farm* text to recreate as a scene in WordsEye, reminding them that they won't be able to include all of the details and vocabulary:

At one end of the big barn, on a sort of raised platform, Major was already ensconced on his bed of straw, under a lantern which hung from a beam. He was twelve years old and had lately grown rather stout, but he was still a majestic-looking pig, with a wise and benevolent appearance in spite of the fact that his tushes had never been cut.

b. Literary Exploration:

- Explain that WordsEye will be a tool to storyboard their *Animal Farm* skits at the final presentation of the Summer Academy, where the storyboards will be enlarged to poster-size and presented. Start discussion on how they can use WordsEye to plan their skit scenes Have students work in groups to create their skit scenes. They can divide the skit into beginning, middle, and end. Each scene should include the background & foreground for what the audience will see during the performance.
- Save each scene in My Portfolio, and then turn the scenes into a Picturebook using the Picturebook editor.

c. Share Out:

- Each student presents their scenes to the class. Other students give feedback on how to improve for skits.

Session 4: Animal Farm Study (Part 2)

a. Warm-up:

- Ask students to think of their favorite *Animal Farm* character. Now create a WordsEye scene by placing that character in the middle of New York City. What does the character see? Does the street scene look different because of this character's presence there?

b. Literary Exploration:

- Have students continue designing scenes for their *Animal Farm* skits. Scenes should be finalized by the end of the session. Tell students that the completed scenes will be made into posters and displayed at the final presentation.
- Save each scene in My Portfolio, and then turn the scenes into a Picturebook using the Picturebook editor.

c. Share Out:

- Have each student volunteer to present their scenes to the class. Other students should provide feedback on how scenes could be improved to make a quality presentation.

Session 5: Final Presentation

- Have each group present their WordsEye creations to the class, giving a synopsis of their stories and showing panels of their work. Have class discuss each scene: characters, imagery, text, connection to *Animal Farm*.

1. Conduct a focus group asking students to discuss:

2. What was the one thing you liked best about WordsEye?
3. What was the one thing you liked least about WordsEye?
4. Did WordsEye help you better understand Animal Farm? If so, how?
5. Would you use WordsEye on your own time?
6. What did you have to change about your writing in order to interact effectively with WordsEye?
7. How is communicating with a computer different than communicating with another person?
8. What are some other uses of the WordsEye platform?
9. What are other things would you like WordsEye to do?

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