Model of Figure-Ground Cognition in Literary Text

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Abstract
Cognitive mechanisms and nerve systems are an important issue in the phylogeny of living organisms. Human consciousness has long been studied, with various models being developed, and the discussion still continues today. Originally generated for visual perception, gestalt psychology introduced the idea of figure and ground to describe our mechanism of attention. We have come up with a method to model such figure and ground relation. We have applied this method to model how a figure and ground relation may be applied to story characters when reading a literary work. We compared this result with a control resulting from randomly generated input matrix. The resulting graph generated from text has characteristics changes. The changes in the graph reflect a dramatic shift in character attributes. Such drama may encourage the reader to anticipate what comes next in the story.

Keywords: literature, anticipation, lattice theory, rough set theory, non-Boolean lattice.

1 Introduction

Consciousness has been a topic of discussion when considering the characterization of life (Edelman, 2005; Arhem, 2007) and artificial intelligence (Dubois, 2007; 2009). As a model for consciousness for humans, gestalt theory introduced the idea of figure and ground as a model of cognitive mechanism (Koffka, 1935). Gestalt theory was used recently in the consideration of a model for consciousness (Forti, 2009). We introduced a mathematical method to model gestalt theory of figure and ground contrasts and used this method to measure the difference between the anticipated reading process by the reader and the actual outcome of the text created by the writer (Kitamura, 2009). In this model we assume that when we are exposed to a story, we process the information as a figure-ground structure, just as we do for visual perception. We apply the rough set derived lattice method to literary text to objectively extract figure and ground based on the available information a conscious mind may perceive. The result based on the text shows a trend of changes throughout the story, unlike the control experiment based on randomly generated input matrix.

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2 Methods

The relationship of figure and ground has two characteristics. They constitute the whole and they do not intersect. Such conditions can be modeled by complement relationships in lattice structures (Birkhoff, 1967; Davey and Priestley, 2002). Let X and Y be two elements of the universal set U and the empty set be ϕ. If X and Y are in a complement relation, their least upper bound is the universal set, $X \vee Y=U$, representing the two elements constituting the whole, and their greatest lower bound is the empty set, $X \wedge Y=\phi$, meaning that the two elements do not intersect.

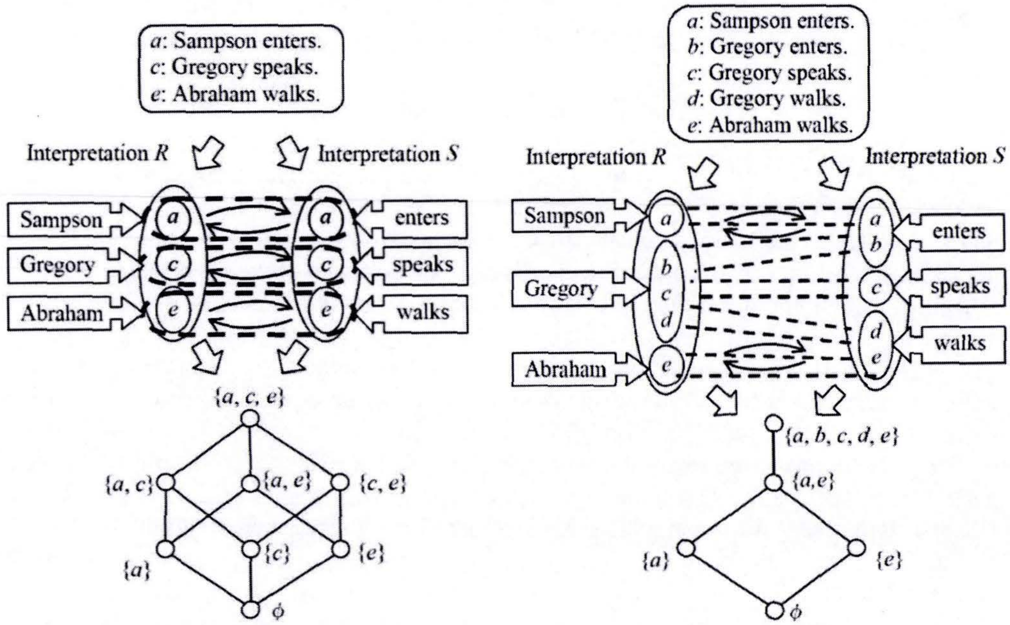
Generally, only Boolean lattices are obtained when a set lattice is constructed from a set of elements. To construct diverse lattice structures that correspond to the various inputs scenarios, we employ the rough set derived lattices (Gunji and Haruna, 2010). These lattices are constructed by preparing two interpretations of a single universal set. For our investigation, we use the sentences as the universal set and subjects of the sentences as one of the interpretations (denoted as R) and the actions (mainly verbs) taken by the subjects as the other interpretation (denoted as S).

The subsets of sentences grouped together under the category of "subjects" are called equivalence classes. The source of the lattice elements are the equivalence class of the desired interpretation initially chosen. Each equivalence class is examined as to whether it forms a Galois connection with the equivalence class of the other interpretation. If they do, that equivalence class is considered to be a fixed point and thus an element for the lattice. For the closure operator to test the Galois connection, two equations of rough set theory, explained below, are used. This procedure is repeated for the power set of the equivalence classes.

Rough set theory is an approximation method of a set X. Let $x, y \in U$ be elements of a universal set U and f be a transformation function. When $f(x)=f(y)$ then x and y are said to have an equivalence relation R. Then an equivalence class is expressed as $[x]_R=\{y \in U|xRy\}$. If the exact boundary of X is unknown, it can be approximated by the lower approximation $R_*(X)=\{x \in U|[x]_R \subseteq X\}$ and the upper approximation $R^*(X)=\{x \in U|[x]_R \cap X \neq \phi\}$. Rough set theory is convenient when applied to form Galois connection since the two approximation methods of rough set theory are two expressions of the same object.

In general, when a closure operator is constructed from only one interpretation R such as $R_*(R^*(X))$, we will always obtain a Boolean lattice where all elements satisfy distributivity, i.e. $A \wedge (B \vee C)=(A \wedge B) \vee (A \wedge C)$ for $A, B, C \subseteq U$, and complementarity, i.e. for any $X \subseteq U$ there exists $Y \subseteq U$ such that $X \vee Y=U$ and $X \wedge Y=\phi$. However, when two interpretations R and S are considered $R_*(S^*(X))$, X will not always result as a fixed point. This allows us to obtain diverse lattice structures, both Boolean and non-Boolean.

Figure 1 (a) shows a diagram when the interpretation R and interpretation S have the same equivalence classes ($\{a\}$, $\{c\}$, $\{e\}$), or also when two interpretation R's are used for the case of $R_*(R^*(X))$ (replace interpretation S with interpretation R). This situation would always return Boolean lattices, since each equivalence class forms a fixed point, indicated by the black arrows forming a Galois connection. The universal set is the sentences *a*, *c*, and *e*. Interpretation *R* is for subjects and interpretation *S* is for actions (attributes of the subjects).



(a) (b)

Figure 1: (a) A diagram showing the rough set derived lattice creation process in the case when the two interpretations result in the same equivalence class formation. (b) A diagram showing the rough set derived lattice creation process in the case when the two interpretations provide different equivalence class patterns. Not all equivalence classes necessarily form a fixed point. Therefore we can obtain lattices other than Boolean lattices, depending on the input.

Figure 1 (b), on the other hand, results in two different equivalence class patterns when we apply two interpretations *R* and *S*. Some equivalence classes do form a Galois connection, resulting as a fixed point, indicated by the black arrows forming a closure. The resulting lattice uses only the fixed points of the power set of the smallest equivalence class for their elements. The other equivalence classes do not form a fixed point, therefore are dropped from the lattice.

To quantify the resulting diverse lattices, we consider the existence rate of complements,

$$\text{complementarity} = \frac{\text{number of elements with complements}}{\text{total number of elements in a lattice}},$$

and the possession rate of complements per element,

$$\text{non-distributivity} = \frac{\text{total number of complements}}{\text{number of elements with complements}}.$$

Complementarity has a value between 0 and 1, and non-distributivity has a value greater than 1.

We organize the text information in a relation table where 1's indicate the presence of a relation between the subject and its attribute, and 0's indicate the lack of such relation (Tables 1, 2 and 3). The relation patterns result in particular lattices.

Whether the subjects form a fixed point or not is conducted in the following way by using a relation table. In Table 2, take *s*3 as *X* for example. We apply the upper approximation in terms of attributes, that is $S^*(X)$. The upper approximation in terms of attributes is an operation to collect all elements that are related to *s*3 in terms of attributes. We obtain *a*3. Then we apply the lower approximation in terms of subjects, that is $R_*(S^*(X))$. The lower approximation in terms of subjects is an operation to only collect elements that fit within the attribute of $S^*(X)$. We obtain *s*3. A fixed point closure $R_*(S^*(\{s3\}))=\{s3\}$ holds. Therefore *s*3 is a fixed point.

We provide one more example. Again in Table 2, take *s*2 as *X*. We apply $S^*(X)$ and get $S^*(\{s2\})=\{a2, a3\}$. Next we apply $R_*(S^*(X))$ and acquire $R_*(S^*(\{a2, a3\}))=\{s2, s3\}$. We start with $\{s2\}$ and finish with $\{s2, s3\}$. Therefore *s*2 is not a fixed point.

Table 1 shows an example when each of the subjects has a unique attribute which does not overlap. This is a situation shown in Figure 1 (a) and results in a Boolean lattice as in Figure 2. In Figures 2, 3, and 4, the complement element pairs have small circles at the same location with respect to the larger element circle. In Figure 1 (a) and Figure 2, a clear figure and ground relation is formed for all subjects. For each subject, the rest of the subjects are contrasted. This suggests each subject can be pointed to as being the figure or the ground (it can be either figure or ground depending on the perspective). For Boolean lattices, the complementarity and non-distributivity are both 1.

Table 1: A relation table indicating each subject has its own attribute and no overlapping attributes.

		Attribute (actions)		
		*a*1	*a*2	*a*3
Subject	*s*1	1	0	0
	*s*2	0	1	0
	*s*3	0	0	1

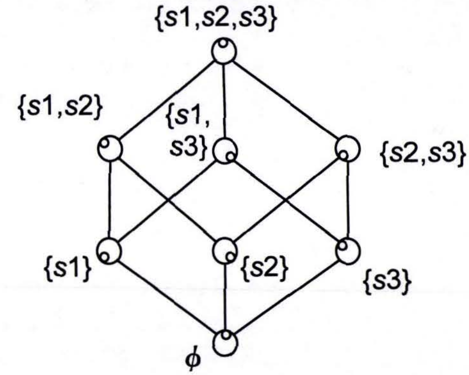


Figure 2: A Boolean lattice resulting from Table 1.

Table 2 shows an example when the attributes of the subjects have an inclusion relation. Such an inclusion relation can also be seen in the lattice structure in Figure 3. In this lattice the only figure and ground relation is between the universal element {*s*1, *s*2, *s*3} and the empty element ϕ, an all-or-nothing relation, since the middle elements have no complements. As a result, the complementarity is less than 1. Because there are no overlapping complements in any of the elements, the non-distributivity is 1.

Table 2: A relation table indicating the attributes of the subjects have an inclusion relation.

		Attribute (actions)		
		*a*1	*a*2	*a*3
Subject	*s*1	1	1	1
	*s*2	0	1	1
	*s*3	0	0	1

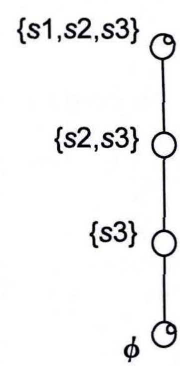


Figure 3: A distributive lattice resulting from Table 2.

Table 3 shows an example when the attributes of the subjects slightly overlap with the other subjects at different attributes. Notice that the 1-0 arrangement in the relation table is opposite that of Table 1. Figure 4 is a resulting lattice from Table 3. Elements {*s*1}, {*s*2}, {*s*3} have complements with the rest of the elements, and therefore possess multiple complements. Again, this lattice has a figure and ground relation only between the universal element and the empty element as in Figure 3, but in Figure 4 the middle elements have multiple complements. As a result, the non-distributivity is greater than 1 and because all elements have at least one complement, the complementarity is 1.

Table 3: A relation table indicating the attributes of the subjects slightly overlap with the other subjects at different attributes, but none of the attributes of the subjects are ever completely included in the other subjects' attributes.

		Attribute (actions)		
		*a*1	*a*2	*a*3
Subject	*s*1	0	1	1
	*s*2	1	0	1
	*s*3	1	1	0

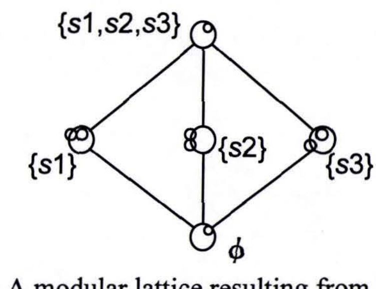


Figure 4: A modular lattice resulting from Table 3.

We applied this method to examine the figure and ground relation of text. We used the modern version of Act 1 Scene 1 of *Romeo and Juliet* by Shakespeare (Yates-Glandorf, J. B. [Ed.], 1985) to obtain complementarity and non-distributivity and compared them with randomly generated values. We consider the sentences as the universal set *U* and subject characters and their attributed actions (verbs) as the two interpretations of the sentences. An arbitrary number of sentences is considered in one instance. We call this number of sentences considered as the "window size." The larger the window size, the greater the number of sentences considered. These number of sentences considered is the universal set. We fix the size of the window and slide it along the story, picking up a new sentence and discarding the oldest sentence in the window of consideration. We construct a lattice based on subjects, therefore we find fixed points for the equivalence classes in the subject set interpretation. The verb attributes used are *enter*, *speak* (the lines by each character), *strike down their swords*, *fight*, *stay*, *pause*, *exit*, *thumb nose*, *draw sword*, *wave sword*, and *hold back*. All verbs are explicitly stated in the narration, except for *thumb nose*, *draw sword*, *wave sword*, and *hold back*. These were chosen by judging from the context or reactions of the other characters. The repetitive conversations in the beginning between Sampson and Gregory and in the end between Benvolio and Romeo are shortened to make the consideration more compact. Complementarity and non-distributivity are calculated for each resulting lattice. The control experiment for complementarity and non-distributivity is created by randomly assigning 1's and 0's to the relation table. The relation table size is the same as those obtained from the actual text at the same step.

3 Results

Figure 5 shows the non-distributivity from Act 1 Scene 1 of Romeo and Juliet. The horizontal axis is the story steps. The vertical axis is the window size which determines the number of data points per trial. The smaller the window size, the greater the number of data points. At window size 62, there is only one data point available since there are 62 story steps and the entire 62 steps of the story are considered. We started measuring from window size 3 (the first line at the bottom of the triangle). The z-axis is the non-distributivity. In our discussion, the exact value of the non-distributivity is not important.

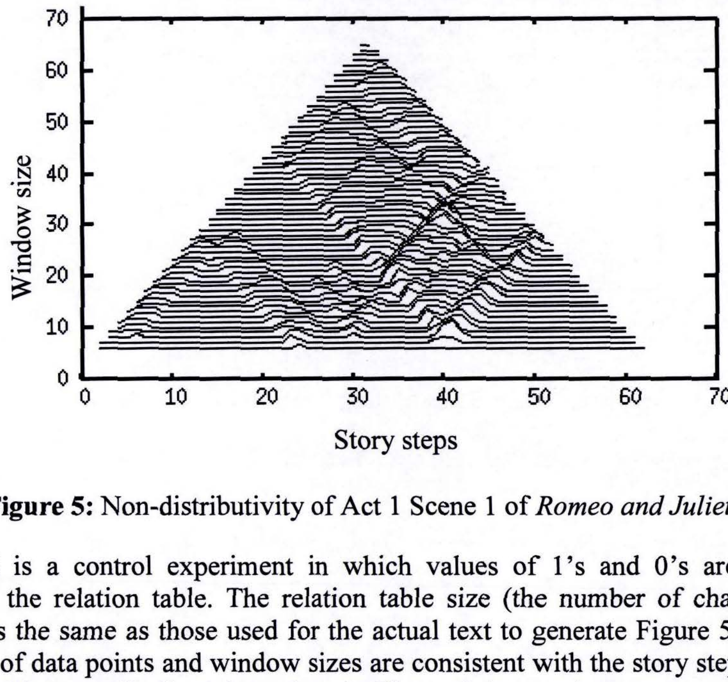


Figure 5: Non-distributivity of Act 1 Scene 1 of *Romeo and Juliet*.

Figure 6 is a control experiment in which values of 1's and 0's are randomly assigned to the relation table. The relation table size (the number of characters and attributes) is the same as those used for the actual text to generate Figure 5. Therefore the number of data points and window sizes are consistent with the story steps provided in Figure 5. The non-distributivity values in Figure 6 do not show a strong trend along the horizontal axis (story steps). While the window size is small (toward the bottom of the triangle), there is little change in the graph values. The difference between Figure 5 and Figure 6 becomes more significant when the window size becomes larger. Generally, a larger window size allows a larger relation table size, which results in greater variation in output values. When the window size is small, there will be less variation in the combination of 1's and 0's in the relation table.

In Figure 5, when we look at window size 4 (the third horizontal line from the bottom of the triangle), the non-distributivity rises at story step 6, between 23 and 25, at 30, and between 39 and 42. The rest of the sections have a non-distributivity of 1, the lowest possible value. The non-distributivity is the greatest at story step 41. However, in Figure 6 it is harder to notice such distinctions.

Figure 7 shows the complementarity from the same section of *Romeo and Juliet* as in Figure 5. The horizontal axis and the vertical axis are the same as Figure 5. The z-axis is the complementarity. In our discussion, the exact value of the complementarity is not important. For window size 4 (the third horizontal line from the bottom of the triangle), we can see that the complementarity drops from the maximum value of 1 much of the time and maintains its value for a while.

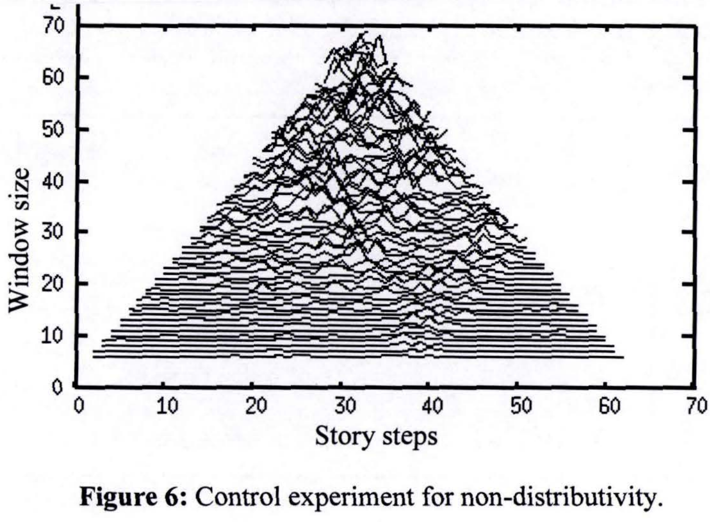


Figure 6: Control experiment for non-distributivity.

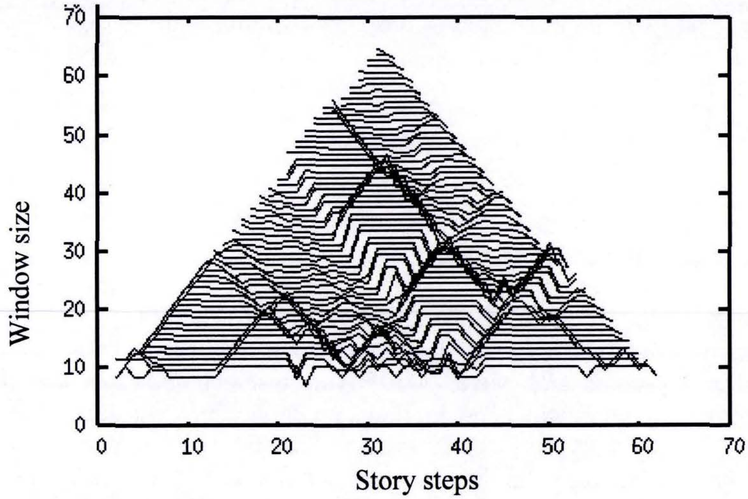


Figure 7: Complementarity of Act 1 Scene 1 of *Romeo and Juliet.*

Figure 8 is a control experiment based on randomly generated input matrix. Since the control experiment consists of randomly generated values, it is harder to see a trend compared to Figure 7.

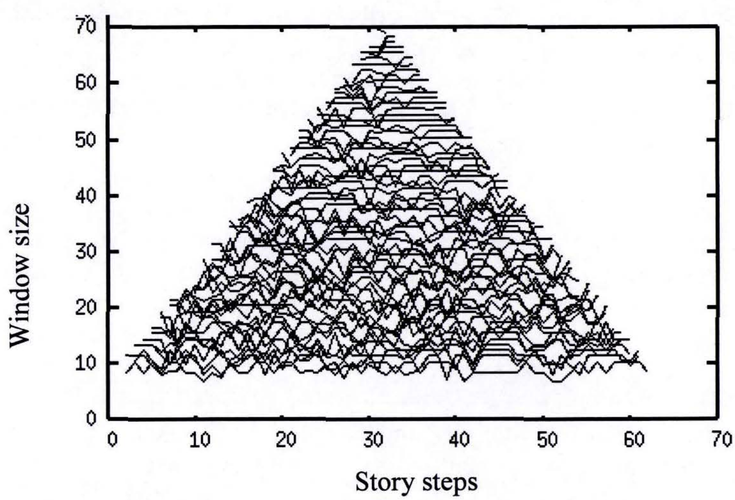


Figure 8: Control experiment for complementarity.

In Figure 7 for window size 4 (the third horizontal line from the bottom of the triangle), we can see that the complementarity drops from the maximum value of 1 much of the time and maintains its value for a while, then shifts its value occasionally. In the control experiment in Figure 8, the values are scattered between 0 (minimum) and

1 (maximum) and there is no apparent trend in the timing and the extent to which the complementarity changes, compared to the graph based on a story as in Figure 7.

4 Discussion

Language plays an important role when considering consciousness. The Aristotelian view considers consciousness as having three types: "plant consciousness", "animal consciousness" and "human consciousness" (cf. Ross 1961, Aristotle, De Anima). The distinction between the first two and "human consciousness" is its relation to language (Allwood, 2006). The necessity of natural language for the brain to be self-conscious has been demonstrated by using phase space trajectory, treating the brain as a dynamical physical system (Neuman and Nave, 2010). This research indicates that the role of language cannot be ignored when considering a model for consciousness.

A story in a literary work involves language. In our figure-ground analysis of a story, there is a difference between the data resulting from a story (Figures 5 and 7) and the plots of randomly generated control values (Figures 6 and 8). Non-distributivity rises when the attributes of the characters are partially overlapped and partially distinct at the same time as demonstrated in Table 3 and Figure 4. In Figure 5 for window size 4, non-distributivity rises when Sampson thumbs his nose at step 6, when Benvolio strikes down the swords of the fighting servants between steps 23 and 25, when officers and citizens speak at step 30, and when most of the characters leave the stage while Montague, Lady Montague, and Benvolio remain on stage between 39 and 42. The non-distributivity rises at these points, not necessarily because of a particular attribute of one of the characters, but because of the attribute relationship with respect to the attributes of the rest of the characters, within that window of consideration.

Complementarity decreases when the attributes of one character fit within the attributes of another character as demonstrated in Table 2 and Figure 3. In Figure 7 for window size 4, at step 3, while Sampson and Gregory *enter*, *speak*, and *draw their sword*, Abraham and Balthasar only *enter* onto the stage. Between steps 6 and 14, the attribute of Gregory and/or Abraham is included mainly in the attribute *speak* of Sampson. At step 22, the attributes of Gregory fit within the attributes of Sampson and the attribute of Balthasar fits within the attribute of Abraham. Between step 27 and 42 various characters go in and out of the attributes of the other characters, and after step 56 Benvolio's attributes *speak* and *exit* fit within the attributes of Romeo during most of the steps.

When the values of non-distributivity and complementarity are both 1, this means that the subjects' attributes are assigned so that the subjects (except for some subjects that may be grouped together because of their similar attributes) will be recognized as having a figure and ground relation as indicated by Table 1 and Figure 2. When only the complementarity is low or only the non-distributivity is low, this suggests that the only figure and ground relations that can be recognized in the story are the all-or-nothing relations. When the complementarity and non-distributivity both are away from the value 1, the resulting lattice is a mixture of elements with no complements and elements with multiple complements, making the figure and ground recognition more complex.

A story's flow can be captured by such shifts in the clarity of figure and ground in the consciousness. For the control experiment generated by random values in Figures 6 and 8, we do not observe an orderly figure and ground status. Although not yet investigated, we speculate that such random result may be obtained from an abstract poem or a novel, which may not have a consistent story intended to be recreated in our mind and therefore making it impossible to anticipate or imagine the story line. For a coherent story such as Romeo and Juliet (Figures 5 and 7), there is a large difference in the figure-ground result, making it easier for a reader to anticipate what may happen next in the story.

The non-distributivity and complementarity reflect the subject-attribute relationships of the characters that appear in the story, reflecting our recognition of the story through figure and ground structure. However, the control experiment does not offer such insight. A coherent story allows the reader to recognize events that take place and anticipate (Miall, 1990; 1995). Our analysis by using the rough set derived lattice method shows that the relationship of subjects and their attributes in a meaningful story is not a randomly scattered relationship, but is designed such that our mind can understand, regenerate, imagine, and anticipate the story, reflecting one aspect of human consciousness (Velmans, 2009).

5 Conclusion

We have introduced a model that represents the notion of figure and ground introduced by gestalt theory. When we applied this model to literary text, the output reflects the various subject-attribute relations present in the text. There is an evident difference between the results from text analysis and results from the control experiment with randomly generated values. We have interpreted this difference as the presence and lack of consciousness. One reflects the presence of consciousness with understanding, imaging, and anticipating when actively engaged in a literary story and the other represents a disorderly signal that does not represent any such meaningful information. Although our model is limited for capturing the rich psychological states (i.e. subconscious, unconscious, subliminal, etc.), it may serve as a method for modeling one aspect of consciousness such as figure and ground contributed by gestalt psychology.

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