Modeling of Changing Logical Structures when Unanticipated Information Emerges

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Abstract
Anticipation involved in our reading process deepens our experience, supporting the sense of understanding, suspense, and surprise. Rough set driven lattice is a suitable tool for analyzing subjective phenomenon such as reading because 1) it produces Boolean as well as non-Boolean lattices that reflect the input information, and 2) this method requires two interpretations of a target, such as subject and attribute, which a sentence provides. By using this method, we can compare how a logical structure resulting from reading with anticipation is different from the information revealed by the actual text. The difference is quantified by complement properties of a lattice, through complementarity and non-distributivity.

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

1 Introduction

Anticipation is one of the important components of a literary reading process (Miall, 1995), more so in stories than in essays (Olson et al., 1981). Anticipation plays a role in inducing the feeling of suspense when reading suspense stories, even if the outcome of the event is already known (Hoeken et al., 2000). In the process of reading literary text, we do not wait until the end of the story to assume the themes of the text or the implications of the actions taken by the characters. Such assumptions are based on the information revealed in the text so far. The text continues to uncover additional information which allows the reader to renew his/her understanding (Miall, 1990). The reading process requires the reader to reformulate her/his scenario of the story by making corrections and adjustments. This indeterminacy in the situation and the continuous effort to formulate the outcome of the system reminds us of the one-to-many model of biological systems described by internal measurement (Matsuno, 1991).

We propose a model of literary reading process that shows the gap between anticipated information and actual information. This model uses lattice structure constructed from subject and attribute information of a sentence. The gap in outcome is caused by the difference in the similarity and dissimilarity of attributes assigned to the subjects. Since the lattices constructed with our method are made with minimum information about the similarity and dissimilarity, therefore identical attribution profile

or subject profile are combined. Thus, for the lattice to result differently, the reader must anticipate and assign different attribute patterns previously nonexistent. Constructing lattices with elements that reflect a subject and attribute relationship allows us to construct Boolean as well as non-Boolean lattices, reflecting how the reader captures the story.

2 Methods

In order to obtain a lattice that reflects a set of diverse sentences, we organize them according to subject and attribute. These subjects and attributes are considered to be two different interpretations of a sentence. The elements of the lattice are fixed points that form a Galois connection between the equivalence groups of the two interpretations, or subject and attribute. Equivalence groups are a subset of elements of a universal set that are considered equivalent in view of the equivalence relation applied to the universal set.

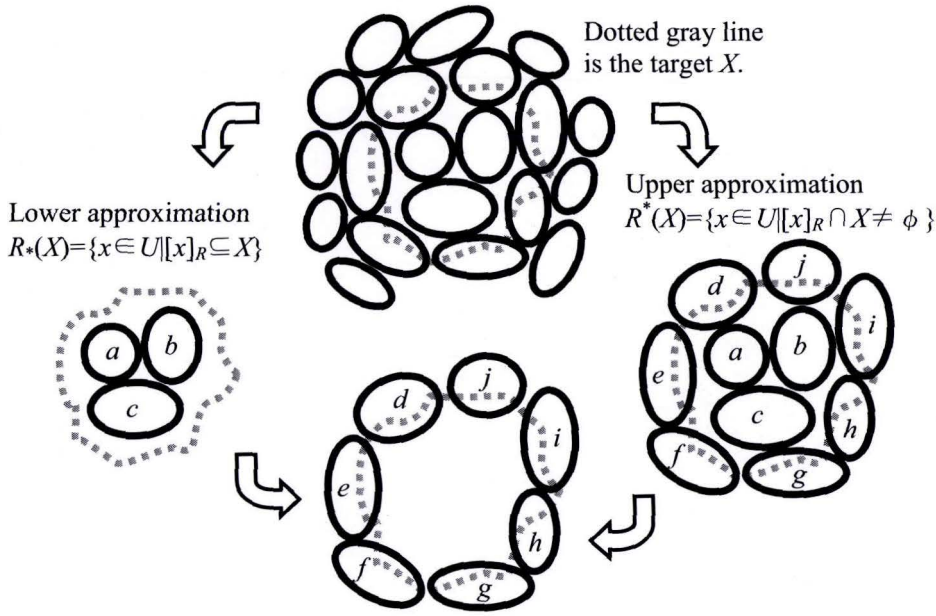

Figure 1: Diagram describing rough set theory

The two functions of rough set theory are used to examine the formation of a Galois connection among the equivalence groups. The two functions are applied in sequence to test whether the equivalence groups form a closure under such an operation. Rough set theory is an approximation method with two equations to capture a target (Figure 1). Let

X be a target and let x be elements related to the target X. The target X can be approximated as the difference between a set of elements only within the target (lower approximation) and a set of elements within a region that includes the target (upper approximation). Lower and upper approximations are expressed as $R_*(X)=\{x \in U|[x]_R \subseteq X\}$ and $R^*(X)=\{x \in U|[x]_R \cap X \neq \phi\}$ respectively. $[x]_R$ is an equivalence group with elements x.

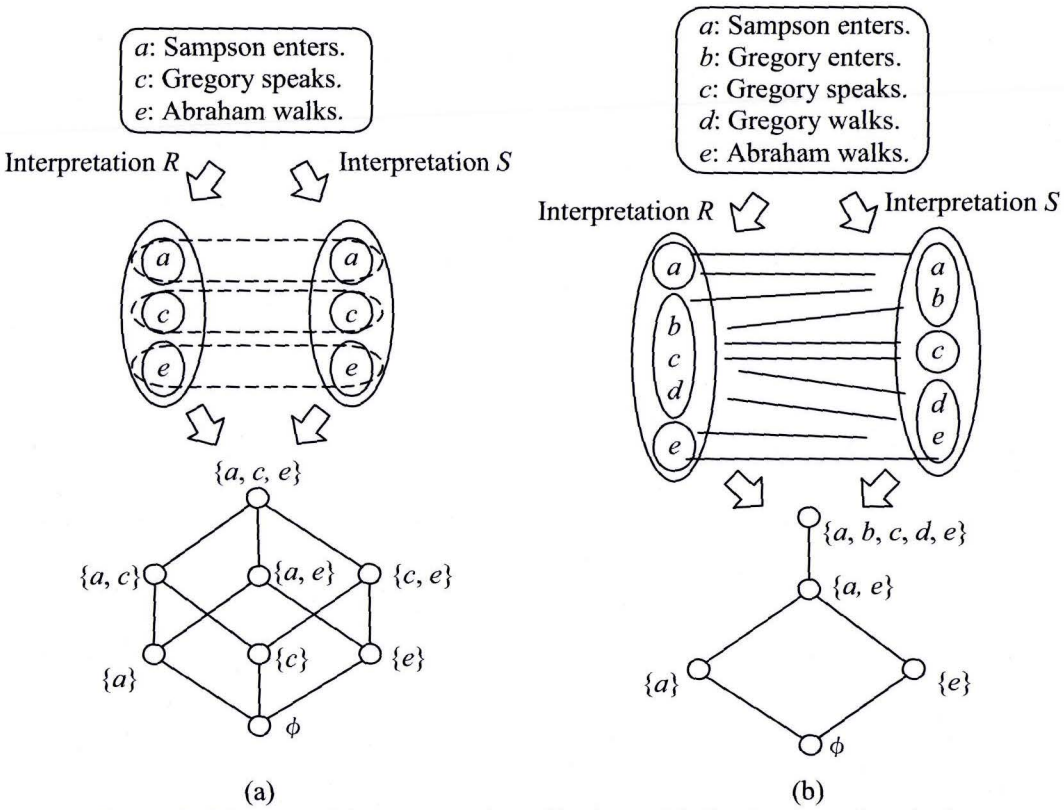

Figure 2: Diagram of the construction of lattices with fixed points of equivalence groups. Lattice in (a) represents the cases when two interpretations are used ($R_*(S^*(X))$ but the two interpretations have the same equivalence groups, analogous to when only one interpretation is used ($R_*(R^*(X))$). Lattice in (b) represents the case when two interpretations are used ($R_*(S^*(X))$, resulting in two different equivalence groups. The lines between the two interpretation groups show that the equivalence groups created by the two interpretations do not form fixed points for every equivalence group.

When we apply these two functions in sequence to X such as $R_*(R^*(X))$, they will always form a closure for every X, since these two functions establish a Galois connection. If the result of the two operations forms a closure, the target is a fixed point. The lattice constructed from these fixed points will always result in a Boolean lattice,

because R is a single interpretation of X and a closure operator on itself will always return itself. Figure 2 (a) will be an analogy of $R_*(R^*(X))$ when we use only the interpretation R. Similarly, Table 1 (a) with subject names in parenthesis will be the case for a single interpretation, $R_*(R^*(X))$.

However, if we introduce two different interpretations for X, such as $R_*(S^*(X))$, it will not necessarily form a closure for every X. If the target X does not form a closure, that X is discarded as an element. Therefore we obtain a Boolean or a non-Boolean lattice. This method is applied to the power set of each equivalence group of one of the interpretations. The fixed points are placed in an inclusion order to construct a lattice. The resulting lattice is called a rough set driven lattice (Gunji et al., 2010).

In Figure 2 (a), the sentences a, b, c have the same equivalence group arrangement for both the subject and attribute interpretation. Therefore, each sentence will be a fixed point. The lattice built from these fixed points forms a Boolean lattice since each element is a combination of each atom element ($\{a\}$, $\{c\}$, and $\{e\}$). This is the same situation when we construct a lattice with only one interpretation, $R_*(R^*(X))$. When the sentences form different equivalence groups with respect to the subject and attribute interpretation, not all equivalence groups become a fixed point, therefore we could obtain non-Boolean lattices (Figure 2 (b)).

Lattices can be quantified by measuring their complementarity and non-distributivity. Complements are a pair of elements in a lattice in which, for any $X \subseteq U$, there exists $Y \subseteq U$ such that $X \vee Y = U$ and $X \wedge Y = \phi$. Complementarity is the existence rate of such complement relationships. It is the ratio between the number of elements with complements and the total number of elements in a lattice. Therefore, if there are elements without complements, the complementarity will be less than 1. Non-distributivity is the complement possession rate. It is the ratio between the total number of complements and the number of elements with complements. Therefore, if there are elements with multiple complements such as N_5 or M_3, the non-distributivity will be greater than 1.

3 Procedure

It helps to organize the subject-attribute information into a matrix of 1's and 0's as seen in Table 1. The number 1 shows the correspondence between the subject and attribute and 0 shows the lack of correspondence. In our examples we focus on verbs for our attribute.

We are interested in building a lattice with elements that consist of subject sets. To apply the rough set driven lattice method, we examine whether a subject or subject set is a fixed point, resulting in $R_*(S^*(X))=X$, where X is the subject or a set of subjects. Assume "Sampson" in Table 1 (b) to be X. By applying the upper approximation of X in terms of the attribute interpretation $S^*(\{\text{Sampson}\})$, collecting all attributes related to "Sampson", we get {enter}. Then we apply the lower approximation in terms of the subject interpretation and collect subjects that "fit" within the collection of attributes obtained earlier, as $R_*(S^*(X))$ implies. Since {Sampson} is the only subject that "fits" within the attribute {enter}, {Sampson} is returned. Since we get

$R_*(S^*(\{\text{Sampson}\}))=\{\text{Sampson}\}$, "Sampson" is a fixed point and therefore an element in a lattice as seen in Figure 2 (b). Now assume "Sampson" and "Gregory" in Table 1 (b) to be X. Apply the upper approximation in terms of the attribute interpretation $S^*(\{\text{Sampson, Gregory}\})$, we get {enter, speak, walk}. Next we apply the lower approximation in terms of the subject interpretation and collect subjects that belong to the attribute condition, $R_*(\{\text{enter, speak, walk}\})$. Since all subjects have the attribute "enter", "speak", and "walk", all subjects are returned, as $R_*(S^*(\{\text{Sampson, Gregory}\}))=\{\text{Sampson, Gregory, Abraham}\}$. Since $R_*(S^*(X)) \neq X$, {Sampson, Gregory} is not a fixed point and therefore not an element in the lattice of Figure 2 (b).

Table 1: A 1-0 matrix showing the relationship between subject and attribute relation. The character names in parenthesis under the verb attributes in (a) show the case when only one interpretation $R_*(R^*(X))$ is used.

(a)

		Attribute (verb)		
		enter (Sampson)	speak (Gregory)	walk (Abraham)
Subject	Sampson	1	0	0
	Gregory	0	1	0
	Abraham	0	0	1

(b)

		Attribute (verb)		
		enter	speak	walk
Subject	Sampson	1	0	0
	Gregory	1	1	1
	Abraham	0	0	1

Every subject in Table 1 (a) will be a fixed point since every subject has a unique attribute, therefore all subject combinations will have a unique attribute set with respect to the rest of the subjects.

4 Results

When each subject has an independent attribute, the resulting lattice would be Boolean as in the lattice of Figure 2 (a) built from the relation of Table 1 (a). When the attributes of the subjects overlap, the characters may not be completely distinguishable. Figure 2 (b) is a non-Boolean lattice built from the relation of Table 1 (b). Even though

Figure 2 (b) is not a sub-lattice of Figure 2 (a) because they do not have the same equivalence groups, Figure 2 (b) has the same structure as the sub-lattice of Figure 2 (a).

Table 2 is an extract from Romeo and Juliet, Scene 1, Act 1. The situation's duration is from the appearance of "officers and citizens" until their exit from stage. Let Table 2 be the basic relation table of the depicted situation. Tables 3 to 5 show variations in anticipative interpretations from Table 2. Figures 4 to 7 show the corresponding lattices. (The character name abbreviations are S=Sampson, G=Gregory, A=Abraham, B=Balthasar, T=Tybalt, Bn=Benvolio, o&c=officers and citizens, C=Capulet, LC=Lady Capulet, M=Montague, LM=Lady Montague, Pr=Prince Escalus, and PrF=Prince Escalus' Followers.)

Table 2: A basic relation table constructed from Romeo and Juliet.

		Attribute (verb)			
		(continue to) fight	enter	speak	exit
Subject	S, G, A, B, T	1	0	0	1
	Bn	1	0	0	0
	o&c, C, LC, Pr	0	1	1	1
	M, LM	0	1	1	0
	PrF	0	1	0	1

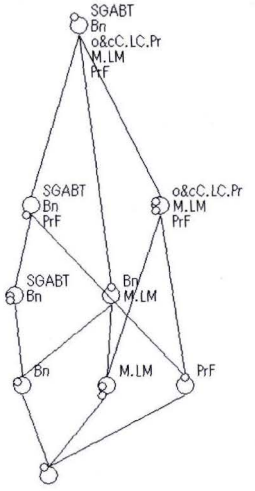

Figure 4: A lattice constructed from Table 2. The matching positions of the smaller circles indicate a complement relationship of the elements.

Figure 4 shows that all elements have at least one complement pair element. There are three elements with more than one complement. The complementarity is 1.0 and non-distributivity is 1.3.

Table 3: A table with an additional attribute "join the fight" added to the subject "officers and citizens (o&c)" in Table 2.

		Attribute (verb)				
		(continue to) fight	enter	join the fight	speak	exit
Subject	S, G, A, B, T	1	0	0	0	1
	Bn	1	0	0	0	0
	o&c	0	1	1	1	1
	C, LC, Pr	0	1	0	1	1
	M, LM	0	1	0	1	0
	PrF	0	1	0	0	1

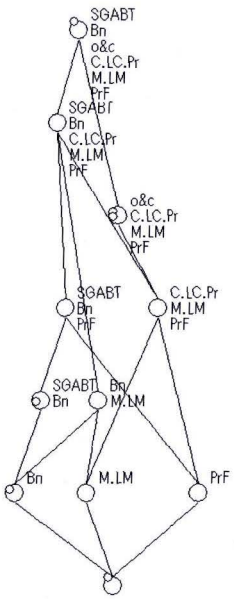

Figure 5: A lattice constructed from Table 3. The matching positions of the smaller circles indicate a complement relationship of the elements. The lattice becomes longer vertically compared to Figure 4.

In Table 3, an attribute "join the fight" is added to the "officers and citizens" in Table 2 although such attribute is not explicitly stated in the text. The added attribute changes the relation table so that the officers and citizens no longer have identical attributes as Capulet, Lady Capulet, and the Prince as in Table 2. In addition, officers' and citizens' attributes cover those of C, LC, Pr, M, LM, and PrF. As a result, in Figure 5 the number of elements with complements decreased and the number of elements possessing more than one complement has decreased. When there is a covering relation in the attributes, the lattice becomes elongated vertically. The complementarity decreases to 0.45 and non-distributivity decreases to 1.2.

Table 4: A table with an additional attribute "stay" added to the subjects Benvolio (Bn), Montague (M) and Lady Montague (LM) in Table 2.

		Attribute (verb)				
		(continue to) fight	enter	speak	exit	stay
Subject	S, G, A, B, T	1	0	0	1	0
	Bn	1	0	0	0	1
	o&c, C, LC, Pr	0	1	1	1	0
	M, LM	0	1	1	0	1
	PrF	0	1	0	1	0

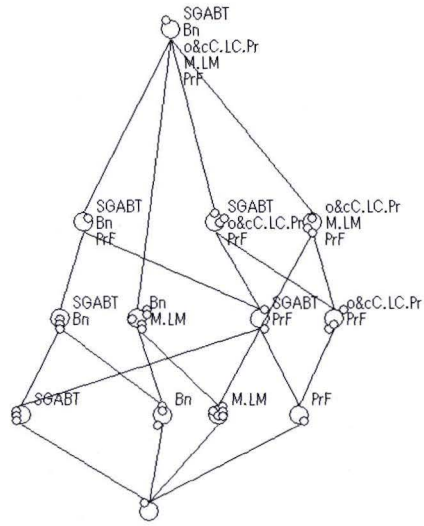

Figure 6: A lattice constructed from Table 4. The matching positions of the smaller circles indicate a complement relationship of the elements. The lattice becomes broader horizontally compared to Figure 4.

In Table 4, an attribute "stay" is added to Benvolio (Bn), Montague (M) and Lady Montague (LM) to the original Table 2, instead of assigning the attribute "join the fight" to the officers and citizens (o&c). The attribute "stay" and the attribute "exit" complement each other so that when the two columns are added, the combined column will possess only 1's. As a result, there is a lesser influence of the covering relation by the {o&c, C, LC, Pr}. All the elements of the lattice in Figure 6 have at least one complement, and most of the elements have multiple complements. When there is less covering relationship and more randomly distributed attribute, the lattice structure tends to expand horizontally. The complementarity is 1.0 and non-distributivity increases to 2.6.

In Table 5, an attribute "join the fight" is added to the officers and citizens and "stay" is added to Benvolio (Bn), Montague (M), and Lady Montague (LM). These additions were separately made in Tables 3 and 4. When these attributes are added together, the resulting lattice reflects the changes of Figures 5 and 6, i.e. the lattice consists of elements without complements and elements with multiple complements. The lattice becomes broader horizontally and longer vertically as seen in Figure 7. The complementarity decreases to 0.59 and non-distributivity increases to 2.0 compared to the lattice built from the original Table 2.

Table 5: A table with an additional attribute "join the fight" added to the subject officers and citizens and "stay" added to Benvolio (Bn) and Prince's Followers (PrF) in Table 2.

		Attribute (verb)					
		(continue to) fight	enter	join the fight	speak	exit	stay
Subject	S, G, A, B, T	1	0	0	0	1	0
	Bn	1	0	0	0	0	1
	o&c	0	1	1	1	1	0
	C, LC, Pr	0	1	0	1	1	0
	M, LM	0	1	0	1	0	1
	PrF	0	1	0	0	1	0

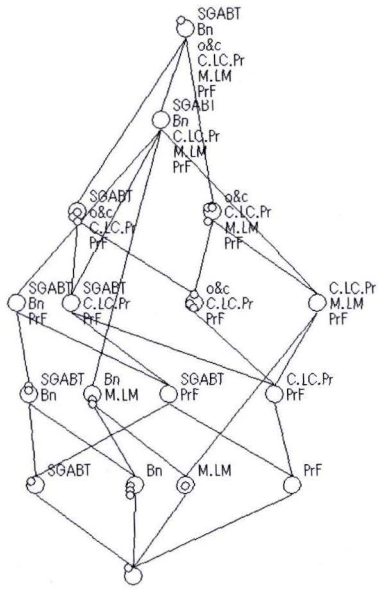

Figure 7: A lattice constructed from Table 5. The matching positions of the smaller circles indicate a complement relationship of the elements. The lattice becomes broader horizontally and longer vertically compared to Figure 4.

5 Discussion

According to Miall the reader of a novel anticipates the overall story. This influences our anticipation to be in agreement or disagreement with the events that take place or have expectations for the following actions of the character. Since an event or an action can be described by a sentence with a subject and attribute, anticipation by the reader can be expressed as additional information generated and assigned to the character/situation's attribution. As the story progresses and the plot is revealed, only relevant information remains and irrelevant information is discarded or kept in the back of our mind potentially for a later time.

The rough set driven lattice reflects two interpretations of the same matter. In our application to the reader's model, the target of analysis is a sentence and we use subjects for one interpretation and the subjects' attributes for the other interpretation. By constructing lattices, we can numerically reflect the differences between anticipated information and the actual information. The values are complementarity and non-distributivity, both related to the distribution of complements in the lattice.

In general, Boolean lattice results when every character is given a distinct feature (Figure 2 (a)). This Boolean lattice has each character as its atom, with complementarity of 1.0 and non-distributivity of 1.0. However, when character attributes begin to overlap, elements of a Boolean lattice are discarded because they do not form fixed points. The

resulting lattice deviates from a maximal Boolean lattice where each character is an atom. Of course, one could also obtain a Boolean lattice which has the same structure as a sub-lattice from the maximal Boolean lattice after discarding specific elements.

When an anticipated attribute is assigned to a subject so that the attributes of that subject completely cover the attributes of the other subjects, as in Table 3, the lattice is elongated vertically (Figure 5) and the complementarity decreases, which means there are elements without complements. On the other hand, if an attribute is anticipated so that it does not cover the attributes of other subjects, but rather increases the randomness of the distribution of the attributes as in Table 4, the lattice expands horizontally (Figure 6) and the non-distributivity increases, which means there are more elements that have multiple complements.

We can quantify the act of anticipation and measure the deviation from the actual situation revealed. Conversely, we can identify how the anticipative attempt was made by observing the change in the resulting values of complementarity and non-distributivity. If the complementarity resulting from the anticipation is low, the assignment of attribute was made so that one of the characters' attributes would cover the attributes of the other characters. Similarly, if the non-distributivity resulting from the anticipation is high, the distribution of attribute to the characters in the situation is random, leaving less possibility for a complete covering relation.

This method could be useful when modeling figure-ground interpretations of literary text (Kitamura et al., accepted) or figure-ground reversal, which is a concept used to describe implications and jokes (Brône 2008; Veale, 2009).

6 Conclusion

Anticipation plays an important role in our reading process. It allows us to be proactively involved with a story, to construct a world unique to each reader. Even if our anticipation continues to be renewed, the act gives us a sense of understanding. A reading experience is enriched by experiencing a feeling of suspense or surprise when new information is revealed. The rough set driven lattice is a convenient tool to assign numerical values to anticipation. Sentences which possess two interpretations, subjects and attributes, are ideal for rough set driven lattice to analyze because this method requires two interpretations of a target. The results obtained show that, when the complementarity of the anticipated subject-attribute profile is lower than the actual text, the reader anticipated attributes of a subject that forms a covering relation with other subjects. When the non-distributivity is higher, the reader anticipated attributes that increase the randomness in distribution of the attributes among the subjects. To further confirm the correspondence of the anticipation model and the act of anticipating in a reading process, an empirical experiment with readers can be conducted.

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