Ascertaining and graphically representing the logical structure of Japanese essays

Tsunenori Ishioka

The National Centre for University Entrance Examinations,
2-19-23 Komaba, Meguro-ku, Tokyo 153-8501, Japan
E-mail: tunenori@rd.dnc.ac.jp

Abstract: To more accurately assess the logical structure of Japanese essays, we have devised a technique that uses end-of-sentence modality and demonstrative pronouns referencing earlier paragraphs as indicators of structure in addition to the conjunctive expressions that have hitherto often been used. This technique will yield better results because conjunctive expressions are intentionally avoided in Japanese. We applied this method to the editorial and commentary (Yoroku) columns of the *Mainichi Daily* newspaper and used it to represent the structure and development of the arguments made by these articles in the form of constellation diagrams, which are used in the field of statistics. We found that the method that does not rely on conjunctive expressions is useful, and the graphical representations are helpful for comprehending the overall flow of the discussion and ascertaining temporal changes in the logical structure of a written essay.

Keywords: logical structure; Japanese essays; automated essay scoring system; graphical representation; constellation diagram; information compilation; modality; natural language processing; visualisation; Japanese.

Biographical notes: Tsunenori Ishioka received his PhD in Statistics at Tokyo University of Science, Japan. He is a Professor in the Research Division, the National Centre for University Entrance Examinations. His research interests include mathematical informatics and data analysis.

1   Introduction

The automated scoring and assessment of essays is currently one of the hottest topics in educational measurements (Shermis and Burstein, 2003; Ishioka and Kameda, 2006). Many scoring and assessment systems have been developed and put into practice. In addition to the pioneering project essay guide (PEG) (Page, 1966, 1994), typical systems include e-rater, which was used until January 2006 in scoring the analytical writing assessment (AWA) that forms part of the graduate management admission test (GMAT) for US business schools (Burstein et al., 1998; Burstein and Wolska, 2003), the intelligent essay assessor (IEA), which measures the conceptual similarities between different texts (Foltz et al., 1999; Landauer et al., 2000, 2003), the BETSY Bayesian

essay test scoring system (Rudner and Liang, 2002), and the IntelliMetric essay scoring software, which is based on rule-based algorithms (Elliot, 1999, 2003). The use of computers in the automated scoring and assessment of essays is thought to be effective, not only because it can eliminate problems such as serial effects of rating (the order in which essay answers are rated) and topic selection (how should essays written on different topics be rated?), but also because it greatly reduces the effort needed for scoring. In recent years, it gives writing guidance on composition to the user interactively, and becomes an important means of providing accountability.

We have developed a system called Jess (Ishioka and Kameda, 2006), which was the first system designed for Japanese texts. This system has not only been published on the web (http://coca.rd.dnc.ac.jp/jess/), but is also available as a windows version for use offline. In February 2005, an article about this system appeared at the headline in the evening edition of the Asahi Daily News, which resulted in it being featured by the Nippon broadcasting system radio station (February 2005), ASAHI PC magazine (April 2006), Yahoo! Internet Guide Japan (June 2006), and Korea Broadcasting system (TV, February 2007). As a result of this publicity, our system is widely known by the general public as well as by people connected with education.

The most important feature of the Jess system is that whereas other existing systems are modelled on professional raters, our system is unique in that it is modelled on documents written by professional writers. Consequently, there is no need to set up scoring models for each prompt, making this the first system that can be operated with small-scale tests in fields where conventional systems would only have been practical for large-scale tests. The essays used as exemplars to train the Jess system were editorials and columns (Yoroku) stored on Mainichi Daily News CD-ROMs. By detecting a statistical outlier to predetermined essay features compared with many professional writings for each prompt, our system can evaluate essays.

The scoring criteria used by Jess more or less adheres to the AWA scoring standard used in the GMAT admission test used by business schools in the USA (GMA-Council, 2005), which evaluates documents from three viewpoints:

1   Rhetoric: Is the document well written?

2   Logical structure: Are the ideas expressed in a well-reasoned manner? Does the discussion have depth?

3   Content: Does the content of the essay respond appropriately the essay prompt?

Of these, 'rhetoric' is evaluated in terms of indicators for which there are relatively clear metrics for good sentences, and for which a general consensus can be obtained. These include the document's readability (sentence length, phrase length, number of phrases, embedded sentences, etc.), the diversity of its vocabulary, the proportion of 'big' words (i.e., words that are long and difficult), and the proportion of sentences written in the passive voice. This viewpoint is perhaps the one most suited to computer evaluation. On the other hand, 'content' presents intrinsic difficulties for computer evaluation, and as a substitute we use techniques such as latent semantic indexing (Deerwester et al., 1990) that measure the semantic similarities between content. This is a common feature of most essay scoring systems, and there are signs that indicate the limits of the technical abilities.

As for 'logical structure', most systems developed for European languages rely heavily on cue words such as conjunctive expressions (Page, 1994; Burstein et al., 1998;

Rudner and Liang, 2002). Consequently, Jess also evaluates and makes judgments based on the following metrics:

- the frequency of occurrence of cue words expressing resultative or contradictory conjunctions (e.g., 'therefore', 'however')

- whether the appearance pattern of cue words is singular.

To make judgments about the appearance patterns of these cue words, Jess uses a trigram model of the appearance of resultative and contradictory conjunctive expressions, and judges the appearance of these cue words to be singular if the occurrence probability in the absence of prior information is larger than the occurrence probability when prior information (gained beforehand from newspaper columns and editorials) is available. In Japanese writing, however, the use of conjunctive expressions tends to alienate the reader, and such expressions, if used at all, are preferably vague. At times, in fact, presenting multiple descriptions or posing several questions seeped in ambiguity can produce interesting effects and result in a beautiful passage (Noya, 1997). In a year's output (365 editions) of the Mainichi Daily News Yoroku column, there are on average 20 editions that contain no conjunctive expressions whatsoever.

Of course, the number of conjunctive expressions that appear in an article is heavily dependent on the length of the article. The Yoroku column contains only about 700 characters, so it is possible to discuss a single topic without using any conjunctive expressions. On the other hand, a longer article such as a 1,200-character editorial requires some degree of logical structure and would be harder to write without conjunctive expressions. Unfortunately, in the essays used in the entrance examinations of Japanese universities and graduate schools, examinees are only required to write roughly 600 to 800 characters. Since the resulting texts are so short, we have to construct a method for ascertaining the overall logical structure without relying solely on conjunctive expressions.

Section 2 of this paper describes a technique for ascertaining the logical structure of documents without relying on cue words. In Section 3, we define the strengths of connections with eight types of conjunctive expressions. In Section 4, we attempt to graphically represent these logical structures with a constellation diagram, which is a statistical tool. A small amount of customisation is needed to achieve this. In Section 5, we introduce the results of applying this technique to the Yoroku and editorial columns in the 2006 Mainichi Daily News CD-ROM. In addition to the overall trends, it is also possible to simultaneously ascertain the properties and the logical transitions of individual compositions. Finally, our conclusions and areas for further study are discussed in Section 6.

2   Ascertaining logical structure without relying on key words

2.1   Use of conjunctive expressions

In the field of automatic summarisation, cue words have often been relied upon for the generation of summary texts – i.e., in order to ascertain the document structure (Mani, 2001; Marcu, 2000). In this context, cue words mainly refer to resultative and

contradictory conjunctive expressions. According to Noya (1997), Japanese resultative conjunctions have four logical types:

- Addition: a conjunctive relationship that adds emphasis. A good example is 'in addition', while other examples include 'moreover' and 'rather'. Omission of such words is not infrequent.

- Explanation: a conjunctive relationship typified by words and phrases such as 'namely', 'in short', 'in other words', and 'in summary'. This type can be broken down further into 'summarisation' (summarising and clarifying what was just described), 'elaboration' (in contrast to 'summarisation', begins with an overview followed by a detailed description), and 'substitution' (saying the same thing in another way to aid in understanding or to make a greater impression).

- Demonstration: a structure indicating a reason-consequence relation. Expressions indicating a reason include 'because' and 'the reason is', and those indicating a consequence include 'as a result', 'accordingly', 'therefore', and 'that is why'. Conjunctive particles in Japanese like 'node' (since) and 'kara' (because) also indicate a reason-consequence relation.

- Illustration: a conjunctive relationship most typified by the phrase 'for example' and having a structure that either explains or demonstrates by example.

There are also four logical types of contradictory conjunctions:

- Transition: a conjunctive relationship indicating a change in emphasis from P to Q expressed by such structures as 'P ..., but Q…' and 'P..., however, Q...'.

- Restriction: a conjunctive relationship indicating a continued emphasis on P. Also referred to as a 'proviso' structure typically expressed by 'though in fact' and 'but then'.

- Concession: a type of transition that takes on a conversational structure in the case of concession or compromise. Typical expressions indicating this relationship are 'certainly' and 'of course'.

- Contrast: a conjunctive relationship typically expressed by 'at the same time', 'on the other hand', and 'in contrast'.

2.2 Methods that do not rely on conjunctive expressions

When these conjunctive expressions are used, it is certainly possible to construct the corresponding logic. However, some conjunctional logic can occur without any of the above conjunctive expressions. Such cases, where explicit conjunctive expressions are omitted, can be detected and judged using one of two methods.

One involves detecting demonstrative pronouns that relate to the previous paragraph. We use the ChaSen system for morphological analysis. When there is a demonstrative pronoun in the first phrase of the first sentence in a paragraph (i.e., the text between the start of the paragraph and the first punctuation mark), this can be regarded as a demonstrative pronoun that refers to the previous paragraph or some part of its content.

Another method is end-of-sentence modality analysis. Modality refers to the speaker's judgment and mental attitude with regard to the content referred to by the text, which varies with the choice of tense, voice and so on. Examples include 'subeki de aru' (should do, have to do) and 'to mirareru' (it seems to be).

Since modality is something that mainly appears at the end of a sentence in Japanese, it is fairly easy to recognise. In the tests conducted for this paper, modality recognition was performed by extracting the last ten characters of each sentence and checking them against a pre-recorded database of sentence ending patterns. As the structure of the system used to classify the end-of-sentence modalities, we used a partially adapted system based on Japanese Descriptive Grammar Research (2003).

For example, the following end-of-sentence modalities indicate resultative conjunctions:

- Addition: 'sō de aru' (be so).

- Explanation: 'to ieyō' (it can be said that), 'to matomerareru' (conclude that), 'to yōyaku dekiru' (summarise that).

- Demonstration: 'kara de aru' (it is because), 'da to kangaerareru' (it seems that).

- Illustration: 'agerareru' (illustrate that), 'rekkyo dekiru' (it follows that).

On the other hand, there appear to be no end-of-sentence modalities in contradictory conjunctions. This is because it is, in fact, hard to imagine how a contradictory conjunction could develop without using contradictory conjunctive expression. Or to put it another way, when the logic of a contradictory conjunction is developed, the conjunctive expression is never omitted so there is no need to consider the end-of-sentence modality.

Of course, there may be some cases where it is not possible to classify a resultative conjunction by processing the end-of-sentence modality. Such cases are regarded as corresponding to addition conjunctions, which are the weakest form of conjunctive relation.

It is thus also possible that there are cases where there is no demonstrative pronoun referring to the previous paragraph and it is not possible to classify the resultative conjunction by end-of-sentence modality processing. In such cases, the degree of resultative conjunction is judged to be weaker than when there is a demonstrative pronoun, so these are labelled as 'addition (assumed)', and the amount of weight applied to the conjunctive expression is reduced, as described below.

2.3   *Labelling experiment*

It is highly unlikely that all eight different types of conjunctive logic will appear in a single column. Even if they do, it is probably not the sort of writing style that a newspaper column has. Therefore, as an example of a column that contains two contradictory conjunctions, the Yoroku (translated) column from the Mainichi Daily News of 13th May 2006 is shown below. To facilitate a discussion of this text, paragraph numbers have been added. Yoroku: according to ancient Chinese folklore, the Big Dipper...

1   In ancient Chinese folklore, the Big Dipper presided over death while the Southern Dipper (a star pattern in the constellation Sagittarius) presided over life. In the 'Sou Shen Ji' ('anecdotes about spirits and immortals') folk tales written in the 4th century, there's a story about someone's life being prolonged by offering food and wine to the Big Dipper and Southern Dipper when they are playing checkers.

2   On the day of the Hare, a young man who had been told by a fortune-teller that he would die soon came across two people absorbed in a game of checkers under a mulberry tree. He poured them some wine and gave them some meat. To return the favour, the Southern Dipper marked the Big Dipper's 'black book' to indicate that the characters for 'nineteen years' should be swapped around so the young man could live until he was ninety years old.

3   I wonder how our own life spans would appear written in the black book of a checkers-playing mountain wizard? Can we rewrite our own allotted life spans? This idea also crossed my mind because I read about the current state of emergency medical care in this newspaper's 'saved lives' campaign project, where it could be said that the lives of patients are left in the hands of the gods.

4   Apparently every year over 100,000 serious emergency cases are liable to be taken to hospitals that are unable to provide adequate treatment. It goes without saying that these are cases where delayed treatment can result in the patient's death. This is happening against a background of ambulance crews operating in systems where they have to make judgments about the severity of a patient's situation and choose which hospital to send the patient to based on this judgment.

5   Emergency hospitals are divided into three ranks on the basis of their ability to cope with serious cases, and ambulance crews have to decide which rank of hospital to send their patients to. But it is not easy to judge a patient's symptoms – one study has shown that 35% of serious cases were regarded as mild to moderate by emergency medical teams, and another found that only about 20% of the serious cases brought into hospital were regarded as serious by ambulance crews.

6   The ambulance crews are also fed up with being pushed into this role of deciding on people's life spans just like a mountain wizard. They want a system where they can first take patients to an emergency centre capable of dealing with any symptoms. After all, it is better to leave our lives in the hands of the gods than to have them determined by systematic shortcomings.

The original column is shown below. To comprehend the flow of the discussion, we extract the first sentence of each paragraph.

1   Mukashi no Chūgoku de wa hokuto shichi sei ga shi wo tsukasadori, nanto roku sei ga sei wo tsukasadoru to iu zokushin ga atta yō da.

2   Ekisha ni wakajini no sō ga aru to iwareta shōnen wa, u no hi ni kuwa no ōki no shita de go ni netchū suru futari ni sake wo nozoki, niku wo sashidasu.

3   <u>Sate</u> dokoka de go wo utsu shinsen no enmachō no wa, jibun no jumyō wa dō kakikomareru no de arō Kimatta jumyō mo kakikaerareru koto ga aru no de arō ka.

4   <u>Sore ni yoru to</u> zenkoku de nenkan 10 man nin ijō mono jūshō kyūkyū kanja ga, jūbun na chiryō no dekinai byōin ni hansō sarete iru kanōsei ga aru to iu.

5 Taiō nōryoku ni yotte 3 ranku no wakareru kyūkyū byōin <u>da ga</u>, kyūkyū taiin wa dono ranku no byōin ni hansō suru ka wo kimeneba naranai.

6 Marude hito no jumyō wo kimeru shinsen no yō na yakuwari wo oshitsukerareru kyūkyū taiin mo tamaranai.

The labels of the conjunctive relations applied to each paragraph of this column are as follows: 2 − addition (assumed), 3 − transition, 4 − addition, 5 − transition, and 6 − addition (assumed). Paragraph 1 provides the initial assertion, so there is no label expressing its connection to the rest of the text. In paragraphs 2 and 6, it is not possible to apply a suitable classification even with end-of-sentence modality processing, so these paragraphs are classified as 'addition (assumed)'. In paragraph 3, the first word 'Sate' acts as a conjunctive expression that indicates 'transition'. Paragraph 4 is labelled 'addition' because the pronoun 'Sore' in the first phrase 'Sore ni yoru to' of the first sentence is judged to refer to an expression in the previous paragraph. Paragraph 5 contains the conjunction 'da ga', and although it does not appear at the beginning, it comes at the end of the first phrase of the first sentence and therefore changes the content of the first phrase. This case is judged to be a 'transition'. In other words, in a contradictory conjunctive expression, we apply the corresponding label if this expression is at the start of the first sentence or in the first clause of the first sentence. We confirmed that these judgments are appropriate by comprehending the paragraph contents.

3   Strength of connection

3.1   Resultative conjunctions

The simplest resultative conjunction structure is assertions added together in sequence. However, simply stringing together a sequence of assertions usually does not lead to any kind of useful argument. The writer must elaborate further on what is being discussed, describe it with specific examples, and back up the arguments being presented (Noya, 1997). Specifically, a structure for the discussion of a resultative conjunction is established by making an assertion and following it with addition, explanation, illustration and demonstration statements as described above.

However, when we consider the flow of arguments − i.e., an assertion is made and maintained, and then an argument is developed based on this assertion − some conjunctive relations are naturally stronger than others. For example, since an addition statement has a conjunctive relation that adds to the assertion, it could be said that it is the weakest conjunctive relation. This is also evident from the fact that explicit addition conjunctive expressions are often omitted. Explanation statements can be further subdivided into 'summary', 'elaboration' and 'restatement' forms, but in any case, they indicate that assertion P and assertion Q are equivalent ($P = Q$). A demonstration statement indicates that assertion P constitutes grounds for assertion Q ($P \rightarrow Q$), and thus could be said to produce the strongest form of resultative conjunction. An illustration is generally not explicit whether the specific example is provided by way of description or in order to demonstrate something. It can be regarded as occupying a position between explanation and demonstration.

The relative strengths of resultative conjunctive relations can therefore be expressed as

addition < explanation < illustration < demonstration.

3.2 Contradictory conjunctions

3.2.1 Transition and restriction

In transition expressions of the form 'P da ga, Q' (P, but Q) or 'P shikashi Q' (P; however Q), it is generally assertion Q that the writer wants to discuss. In other words, first assertion P is presented, and then the subject changes to a contradictory assertion Q. Therefore, this conjunctive relation causes the greatest change in the flow of a discussion.

On the other hand, in a restriction structure of the form 'P tadashi Q' (P, but then Q), the writer is still talking about P and is just providing Q as a supplementary restriction. The strengths of transition and restriction expressions can therefore be expressed as

restriction < transition.

3.2.2 Concession and contrast

A concession expression can be regarded as a type of transition expression. There is only a subtle difference between a simple transition expression and a concession expression, and thus these expressions can be regarded as having more or less the same strength.

On the other hand, in a contrast conjunctive relation, the two parts must have common points and differences. If there are no differences then there is no basis for a contrast, and obviously the same applies if the two parts have nothing in common. The common points in the contrast indicate what the topic is, and the differences indicate what the writer wants to say about this topic. Accordingly, compared with a restriction conjunction, a contrast conjunction can be thought of as having a larger degree of contradictory conjunction in that it contains a point of comparison.

Based on the above argument, the demonstration of contradictory conjunctions can be arranged in order of strength as

restriction < contrast < (concession = transition).

3.3 The inclusion of points indicating logical connections

The only way to grasp the logical flow of a discussion is to ascertain the state of connection of various different assertions; so, if it is possible to figure out how the logic embodied in these resultative and contradictory conjunctions should be strung together, then it ought to be possible to ascertain the logical development of the text. To do this, I will assign positive points to resultative conjunctions and negative points to contradictory conjunctions. Based on the relative demonstrative strengths of the resultative and contradictory conjunctions, these conjunctions are awarded scores ranging from +4 to –4.

For the sake of convenience, resultative conjunctions are scored as addition (assumed) (+1), addition (+1.5), explanation (+2), illustration (+3), and demonstration (+4). Contradictory conjunctions are scored as restriction (–2), contrast (–3), concession (–4), and transition (–4). It is difficult to decide what points should be assigned to the first

paragraph. We decided to award the same points as an addition (assumed), which is slightly weaker than an addition conjunction.

In the example given in Section 2.3, the development of the text from the second paragraph onwards is addition (assumed), transition, addition, transition, addition (assumed). So, in this case the paragraphs (including the first paragraph) are recorded as +1, +1, –4, +1.5, –4, +1. In this way, we can ascertain the overall logical connections. We can also understand the degree of change in the subject of the article.

Here, it is essential that instead of simply applying points ranging from +4 to –4, consideration is also given to the number of characters (i.e., the quantity of discussion) in the paragraphs to which these points correspond. In the example of Section 2.3, the number of characters in each paragraph is as follows:

1   98 characters

2   116 characters

3   122 characters

4   125 characters

5   126 characters

6   99 characters.

We divide these figures by the total number of characters to produce normalised weightings of 98/686 = 0.14, 0.17, 0.18, 0.18, 0.18, and 0.14, which are multiplied by the quantities representing the logical structure.

4   Constellation diagrams

A constellation diagram is a type of graphical representation used for multivariate data which was proposed by Wakimoto and Taguri (1978). A constellation diagram is prepared as follows.

- the observation data for p variables is given in the form $x = (x_1, x_2, …, x_p)$

- each element of x is normalised to the range [0, 1]: $y_i = f_i(x_i)$, $i = 1, 2, …, p$

- these are then converted into angles in the range [0, π]: $\xi_i = y_i \pi$, $i = 1, 2, …, p$

- each element of x is subjected to a variable weighting w_i, where $w_i \geq 0$, and
$$\sum_{i=1}^{p} w_i = 1$$

- taking the origin (0, 0) as a starting point, the operation that proceeding for a distance w_i in the direction of angles ξ_i, is repeated for $i = 1$ to p, and a mark is made at the final point reached. This point lies within a semicircle of unit length centred on the origin

- this is repeated for each of the n items of data $x_1, x_2, …, x_n$ resulting in n points within the semicircle.

This process is illustrated in Figure 1.

Figure 1 Illustration of the constellation diagram concept
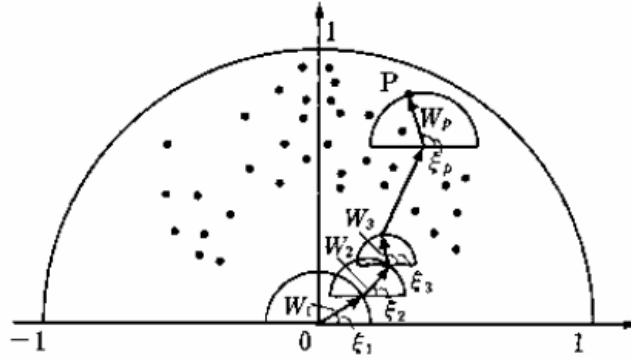
A function $f_i(x)$ that is often used for normalising values to the range [0, 1] involves using the maximum value M_i and minimum value m_i of the n observed values of the ith variable as follows.

$$f_i(x) = (M_i - x)/(M_i - m_i)$$

In the example given in Section 2.3, $M_i = +4$, and $m_i = -4$ are used for all i. Then, the angles $\xi_i(i = 1, \ldots, p)$, where $p = 6$, are $(4 - 1) \pi / (4 - (-4)) = 3\pi / 8$, $3\pi / 8$, $(4 - (-4)) \pi / 8 = \pi$, $(4 - 1.5) \pi / 8 = 2.5\pi / 8$, π, $3\pi / 8$.

The distances w_i in the direction of the angles ξ_i are given as 0.14, 0.17, …, and 0.14, described in Section 3.3.

In the resulting diagram, the approximate direction (that is, trend) can be ascertained from the gradient of the straight line from the origin to the final destination point, and the degree of scatter in $x_i(i = 1, \ldots, p)$ can be ascertained from the distance between the origin and the final destination point; if there is little scatter in x, then the angles ξ_i are more or less the same and the final destination point falls close to the circumference of the semicircle. On the other hand, if there is a large variance in x_i, then there are a wide variety of angles ξ_i and the final destination point falls closer to the centre of the semicircle. Also, with regard to the data x in an essay prompt, if its path is drawn as a polygonal line, then it is possible to understand at a glance the positions corresponding to all the data and the path toward the final destination point.

This sort of constellation diagram can be used to ascertain both the overall distribution and the detailed nature of individual data items.

5 Examples of application to Mainichi Daily News columns and editorials

From the 2006 Mainichi Daily News CD-ROM, 365 columns (Yoroku) and 730 editorials (two per day) were extracted. In the columns and editorials, the paragraphs are explicitly shown. We labelled each paragraph to indicate its conjunctive relation – addition (assumed), addition, explanation, illustration, demonstration, transition, restriction, concession or contrast – and we assigned points ranging from +4 to –4 corresponding to the conjunctive relations determined in Section 3.

The weighting applied to each paragraph is proportionally divided so that the total corresponding to the quantity of text (number of characters) in the paragraphs is normalised to 1.

Source code for plotting constellation diagrams in the R programming language was published by Aoki (2007), but this code cannot be used directly. This is because in an ordinary constellation diagram, the weighting w_i is common to all the data, whereas in this instance the number of paragraphs in each column or editorial (p) is not fixed, so the weightings w_i are different for each set of data. The source code was modified slightly to accommodate this.

Also, to allow the trajectory of a particular dataset to be represented, the software was adjusted so that by passing different function arguments it is possible to choose between a mode where only the final destination point is indicated with a mark, or a mode where the trajectory is also indicated.

The actual analysis results are shown in Figure 2. The results for the Yoroku columns (700 characters, 365 editions) are shown in Figure 2(a), and the results for the editorials (1,200 characters, 730 editions) are shown in Figure 2(b). The intermediate trajectories shown in these figures correspond to the first Yoroku column and editorial of 2006.

Figure 2   Mainichi Daily News CD-ROM 2006 edition, (a) columns (Yoroku; 700 characters, 365 editions) (b) editorials (1,200 characters, 730 editions)
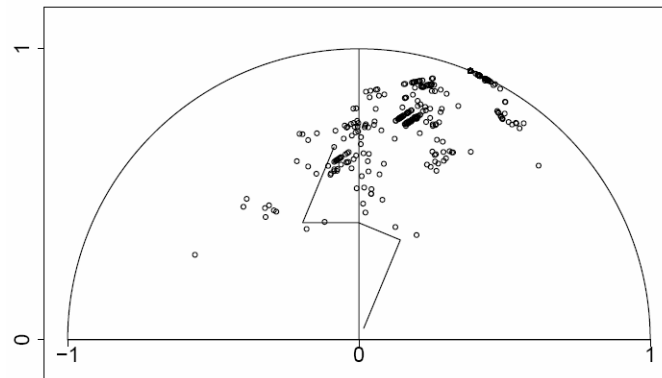
(a)
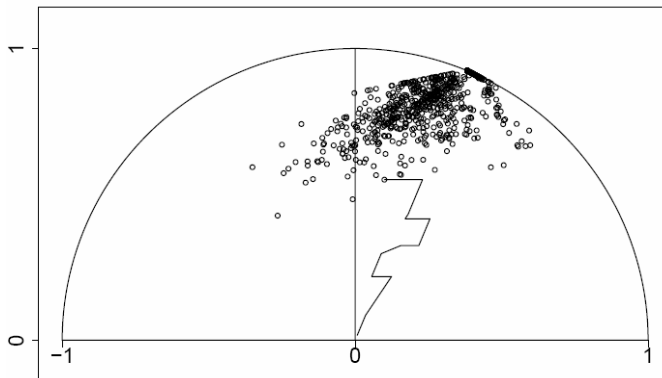
(b)

Right-handed hemisphere area indicates the resultative conjunction structure, while left-handed hemisphere area the contradictory conjunction structure. It is because, for example, the direction of addition relation (+1.5) has an angle of $2.5\pi / 8$ from positive x-axis; the angle is smaller than 05π. While, the direction of transition relation (–4) has an angle of π, which is bigger than 0.5π.

The results obtained from the Yoroku columns in Figure 2(a) show us that:

- Overall, the data is oriented in the +1.5 (addition) direction, showing that many of these articles are logically connected by addition conjunctions.

- By mixing this with the logic of contradictory conjunctions, the overall plot shifts from the top right to the bottom left of the semicircle. Sixty-three of the articles (out of 365) even end up with the final destination point plotted in the left half of the semicircle. One of these is the article whose trajectory is shown in the figure.

The results obtained from the editorials in Figure 2(b) are similar to the results for the Yoroku columns. The majority uses addition logic overall to further the discussions, and there are some cases with which a few contradictory conjunctions are mixed.

So far, the Jess automated scoring system developed by Ishioka (2006) has only relied on conjunctive expressions, so it has been difficult to ascertain the logical structure of a column with a small character count and few conjunctive expressions (sometimes none at all). However, by processing demonstrative pronouns and end-of-sentence modalities as shown in this paper, it becomes possible to ascertain the logical structure without relying solely on conjunctive expressions. In this way, it has been shown that there are no particularly large differences in the style of logical development even in newspaper columns and editorials with different character counts.

In addition to the articles from 2006, we have also applied this technique to data from 1999–2002, yielding similar results. However, in the 2006 edition, the newspaper switched to a larger type size which resulted in a reduction of about 20% in the character counts of both the Yoroku columns and editorials compared with the 1999–2002 period.

6 Conclusions

The way in which arguments and logic are developed in essays depends on the tendencies of the assertions made in these documents; and this can be summarised and visualised by means of the constellation diagram described in this paper. A constellation diagram is a graphical representation method that is highly useful for the descriptive representation of large amounts of data. The diagram can ascertain both the overall distribution and the detailed nature of individual data items.

In most statistical graphing methods, the order in which data appears is not taken into account, because statistical theory itself is normally based on random sampling; however, in this constellation diagram it is possible to see the temporal variation of a particular set of data by showing its intermediate trajectory. It is expected that this graphing method – devised by Japanese statisticians in the field of multivariate analysis – will become a popular and widely used means of summarising and visualising trend information. At least, it helps to evaluate the logical structure of essays. This manner is now implemented into our Japanese automated essay scoring system, Jess.

References

Aoki, S. (2007) 'Constellation graph, statistics in R', (in Japanese), available at http://aoki2.si.gunma-u.ac.jp/R/Constellation.html.

Burstein, J. and Wolska, M. (2003) 'Toward evaluation of writing style: finding overly repetitive word use in student essays', in *Proceedings of the 11th Conference of the European Chapter of the Association for Computational Linguistics*, Budapest, Hungary.

Burstein, J., Kukich, K., Wolff, S., Lu, C., Chodorow, M., Braden-Harder, L. and Harris, M.D. (1998) 'Automated scoring using a hybrid feature identification technique', *The Annual Meeting of the Association of Computational Linguistics*.

Deerwester, S., Dumais, S.T., Furnas, G.W., Landauer, T.K. and Harshman, R. (1990) 'Indexing by latent semantic analysis', *Journal of the American Society for Information Science*, Vol. 41, No. 7, pp.391–407.

Elliot, S. (1999) *Construct Validity of IntelliMetric with International Assessment*, Vantage Technologies (RB-323), Yardley, PA.

Elliot, S. (2003) 'IntelliMetric: from here to validity', in Shermis, M. and Burstein, J. (Eds.): *Automated Essay Scoring: A Cross-disciplinary Perspective*, pp.71–86, Lawrence Erlbaum Associates, Hillsdale, N.

Foltz, P.W., Laham, D. and Landauer, T.K. (1999) 'Automated essay scoring: applications to educational technology', in *Proceedings of EdMedia '99*.

Graduate Management Admission Council (GMA-Council) (2005) *The Official Guide for GMAT Review*, 11th ed.

Ishioka, T. and Kameda, M. (2006) 'Automated Japanese essay scoring system based on articles written by experts', *Proceedings of the 21st International Conference on Computational Linguistics and 44th Annual Meeting of the Association for Computational Linguistics*, Association for Computational Linguistics, pp.233–240.

Japanese Descriptive Grammar Research (Ed.) (2003) *Japanese Modern Grammar*, 4: Modality (in Japanese), Kuroshio Press, ISBN 4-87424-285-5.

Landauer, T.K., Laham, D. and Foltz, P.W. (2000) 'The intelligent essay assessor', *The Debate on Automated Essay Grading, IEEE Intelligent Systems*, Vol. 15, No. 5, pp.27–31.

Landauer, T.K., Laham, D. and Foltz, P.W. (2003) 'Automated scoring and annotation of essays with the intelligent essay assessor', in Shermis, M. and Burstein, J. (Eds.): *Automated Essay Scoring: A Cross-disciplinary Perspective*, pp.87–112, Lawrence Erlbaum Associates, Hillsdale, NJ.

Mani, I. (2001) 'Automatic summarization', *Natural Language Processing*, Vol. 3, John Benjamins Publishing Co.

Marcu, D. (2000) *The Theory and Practice of Discourse Parsing and Summarization*, The MIT Press.

Noya, S. (1997) *Logical Training* (in Japanese), Sangyo Tosho, ISBN 4-7828-0205-6.

Page, E.B. (1966) *The Imminence of Grading Essays by Computer*, Phi Delta Kappan, pp.238–243.

Page, E.B. (1994) 'New computer grading of student prose, using modern concepts and software', *Journal of Experimental Education*, Vol. 62, No. 2, pp.127–142.

Rudner, L.M. and Liang, L. (2002) A*utomated Essay Scoring Using Bayes' Theorem*, National Council on Measurement in Education, New Orleans, LA.

Shermis, M. and Burstein, J. (Eds.) (2003) *Automated Essay Scoring: A Cross-disciplinary Perspective*, Lawrence Erlbaum Associates, Hillsdale, NJ.

Wakimoto, K. and Taguri, M. (1978) 'Constellation graphical method for representing multi dimensional data', *Ann. Statist. Math.*, Vol. 30, Part A, pp.77–84.