Chronological and Geographical Measures for Evaluation of World History Essay QA in University Entrance Exams

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ABSTRACT

We propose a method for measuring chronological and geographical consistency of the world history essays in Japanese university entrance exams. On observing several model answer essays, we found that an essay's uniformity, ordering and cooperability were important features of a well-formed paper, and we introduced them into our method. The experimental result shows a weak positive correlation between the scores measured by the proposed method and the scores estimated by a human expert in world history.

KEYWORDS

essay QA, automated evaluation, chronological and geographical measures, world history, university entrance exams

1 INTRODUCTION

Research on real-world complex question-answering (QA) has flourished in recent years [1]. In the QA Lab tasks [11, 12] at the NTCIR workshop,[1] the current problems and solutions in QA technologies have been investigated using the world history questions in

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[1]http://research.nii.ac.jp/ntcir/index-en.html

Japanese university entrance exams and their English translation. Japanese university entrance exams include various types of questions such as multiple-choice, fill-in-the-blank, true-or-false, map understanding, chronological reordering, short-answer, and essay questions. Above all, essay QA is the most challenging, and still has many open problems, such as the evaluation of essays that QA systems generated. Although there is a way of evaluation by human experts in world history, it takes considerable time and cost. In the case of the QA Lab, evaluation of 46 essays by an expert who teaches world history took around a month and about 500,000 yen (4,500 USD). Therefore, a new method is required.

Because essay generation is regarded as a kind of query-biased summarization, the measures for evaluating summaries using gold-standard data can be applied to essay evaluation. In the QA Lab, the ROUGE family [6] and the Pyramid method [8, 10] are used for grading essays besides a human expert's evaluation. A positive correlation between these grades and those provided by humans was between moderate and weak, and the ranking order by the measures was not always concordant with the ranking order given by the human marks. Therefore, we investigated more appropriate measures for evaluating world history essays in Japanese university entrance exams.

For evaluating summaries, the linguistic well-formedness and the relative responsiveness were used in the DUC workshops.[2] The content, readability/fluency, and the overall responsiveness were used at the Guided Summarization tasks[3] in the TAC workshops. These measures are important for evaluating world history essays in university entrance exams. However, the linguistic well-formedness and readability/fluency were scored arbitrarily by human assessors, while the content was methodologically scored by the ROUGE family and the Pyramid method, among others. We would like to methodologically give other scores based on merits other than the content. For evaluating world history essays, chronological and geographical consistency is important as a kind

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[2]http://duc.nist.gov/duc2007/tasks.html
[3]http://www.nist.gov/tac/2011/Summarization/Guided-Summ.2011.guidelines.html

of semantic consistency. However, how to evaluate these is not obvious. What measures should be taken for chronological or geographical consistency? How should the chronological measures and the geographical measures be harmonized? In this paper, we propose a method for measuring chronological and geographical consistency of world history essays, and examined the method using essays submitted to the QA Lab.

The main contributions of this paper are as follows: (i) to clarify the features of well-formed world history essays in terms of the chronological information and the geographical information, (ii) to introduce a new scoring method based on the features to evaluate the well-formedness of world history essays.

The rest of this paper is organized as follows. Section 2 describes the features of essay questions for world history in Japanese university entrance exams. Section 3 describes the features of model answer essays and the hypotheses about what constitutes a well-formed essay. Section 4 describes a method based on the hypotheses. Section 5 describes the experimental results and give them consideration. Section 6 briefly overviews related work, and describes the utility of our method. Section 7 is the conclusion.

2 ESSAY QUESTION OF WORLD HISTORY

Figure 1 shows an example of an essay question for world history, which is an English translation from the original Japanese version. The question contains additional text besides the main essay topic: "How did political authorities around the world handle religion, religious schools, and people affiliated with them within their territories?" The first paragraph gives background information, and the texts below the essay topic are the constraints for writing the essay. The constraints include a length limitation of "no more than 20 lines," a geographical condition of "West Europe, West Asia and East Asia," a chronological condition of "up to and including the first half of the 18th century," the keywords that must be used in the essay, and other associated conditions. The chronological condition and the geographical condition prove the importance of chronological and geographical consistency.

Note that we distinguish essay questions from short-answer questions in terms of description length. The length of essay is more than ten lines, while the length of short answer is a few lines. Not many universities give essay questions, and the number of essay questions in an exam is usually one or two. This means that it is impossible for a statistical approach to prepare enough training data.

3 WELL-FORMED WORLD HISTORY ESSAY

3.1 Structure

In general, a world history essay is a sequential description of historical events (HEs). A HE has both chronological information and geographical information. Let us consider how this is written. While the chronological information can be easily put in a linear order from the past to the future, the geographical information is not easy to be determinately put in a linear order because of the spatial extent. Based on the study of several model answer essays from past university entrance exam collections, the general structure of the essays follows one of two approaches: (a) disregarding geographical information, all HEs are described in chronological order, and (b)

grouping HEs by the geographical information. In both, information is described in chronological order. If the former is regarded to be grouped by geographical information from "the whole world," there is no difference between the two manners; that is, both are descriptions in chronological order for HEs in a particular area. We defined a sequence of HEs with the same geographical information as a geographical section (GS). GSs could be nested hierarchically. For example, a GS of Europe may contain GSs such as England, France, and Germany, and the GS of England may contain GSs such as London, Birmingham and Manchester.

From the above, we built the following hypotheses for the structure of world history essay.

(H1) An essay is a GS.
(H2) A GS can consist of more than one sub-GSs that is in the parent GS.
(H3) HEs in a GS are put in chronological order.

3.2 Uniformity

Let us consider the uniformity of GSs in a GS. If GSs of the East Midlands, Paris and German are placed on the same level in a GS of Europe, they are incongruous even though they are all parts of Europe. This is because they are in different levels of a geographical category, such as country, region, and city. Therefore, well-formed essay require the uniformity of geographical category level. In addition, if England is described with hundreds of words while France and Germany are respectively described with a dozen words, there is incongruity even though they are in the same geographical category level. This is because their quantities of description are imbalanced. Therefore, well-formed essay seems to require the uniformity of quantity.

We built the following hypotheses for the uniformity of GSs.

(H4) GSs placed on the same level in a GS are in the same level of geographical category.
(H5) GSs placed on the same level in a GS are described in the same quantity.

3.3 Ordering

Let us consider the ordering of HEs in a GS. HEs in well-formed essays are generally described in chronological order. Note that the occurrence order of HEs does not always correspond with the descriptive order of an essay. Since the chronological information of an HE has a beginning and ending in a range, the occurrence order relation between HEs is either non-overlapping, partially overlapping or inclusive as shown in Figure 2. In all relations, the beginning of the HE e_1 precedes the beginning of the HE e_2. However, in the inclusion relation, e_1 may be described after e_2 such as "The Treaty of Nanking ended the First Opium War." Therefore, we assume that the describing order of HEs in the inclusion relation is free to the chronological order. Next, let us consider the ordering of GSs in a GS. The describing order of GSs is free relative to the chronological order. However, for example, the describing order of Athens, Rome, Cairo, Baghdad, Beijing and Shanghai seems to be better than the order of Athens, Baghdad, Beijing, Cairo, Rome and Shanghai. This is because GSs relating to each other are placed closely. We assume that the relativity is approximated by the geographical distance.

We built the following hypotheses for the ordering in a GS.

The following statement is Article 20 of the Constitution of Japan.

Article 20.
1. Freedom of religion is guaranteed to all. No religious organization shall receive any privileges from the State, nor exercise any political authority.
2. No person shall be compelled to take part in any religious act, celebration, rite or practice.
3. The State and its organs shall refrain from religious education or any other religious activity.

The concept of separation of church and state, as expressed in that article, gradually began to prevail in a number of nations from the second half of the 18th century, following the popular revolutions in the United States and France.
   Prior to that time, how did political authorities around the world handle religion, religious schools, and people affiliated with them within their territories? Write a brief essay on this topic in the answer section (A), using no more than 20 lines. Be sure to list specific examples from West Europe, West Asia, and East Asia, up to and including the first half of the 18th century, and compare the characteristics that were apparent among those three regions. You must use each of the seven keywords at least once, and underline those keywords.

Jizya, Acts of Supremacy, Dalai Lama, abolition of the Edict of Nantes, millet system, Lifan Yuan, Landeskirche system

Figure 1: An example of essay question of world history
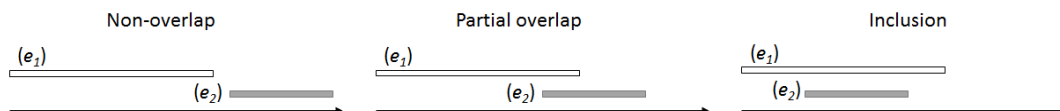
Figure 2: The pattern of chronological overlap

(H6) As an exception to the hypotheses (H3), an HE can be described both before and after another HE if they are in the inclusion relation.
(H7) GSs in a GS are described in the order of short geographical distance.

The hypothesis (H6) is the complement of the hypothesis (H3).

3.4 Cooperability

Let us consider the cooperability of a world history essay to question constraints in terms of the chronological and the geographical information. As described in Section 2, world history essay questions give chronological and geographical conditions such as "up to and including the first half of the 18th century" and "West Europe, West Asia and East Asia." In this case, if an essay describes only the ancient histories of West Europe, West Asia and East Asia, the essay satisfies the conditions logically. However, it does not reflect the question intention. Since question answering is a kind of conversation, a well-formed essay will observe the cooperative principle in conversation, known as Grice's Maxims [5], which consist of quantity, quality, relation, and manner. The essay which describes only the ancient histories violates the maxim of quantity, and the cooperative essay should describe at least one HE of the 18th century. The geographical information is also similar. For example, an essay describing only "West Europe and West Asia" violates the maxim of quantity, and the cooperative essay should describe at least one HE for each area of the geographical condition. Note that a GS that is a part of an essay can violate the maxim of quantity even though the essay is cooperative. For example, the GS of West Europe in a cooperative essay may not describe all countries in West Europe. We assume that the chronological cooperability is observed in all GSs while the geographical cooperability is observed in only a GS corresponding to the essay. For a GS, we defined a period from the beginning of the earliest HE to the end of the latest one as a period of the GS. The smallest geographical range, including where the HEs in a GS occurred, was defined as the range of the GS. We assume that the observance of the maxim of quantity is approximated to the coverage of the period and the range of GSs.

We built the following hypotheses for the cooperability on the chronological and the geographical conditions in questions.

(H8) A period of a GS covers the period of the chronological condition as justly as possible.
(H9) A range of a GS corresponding to the essay covers the range of the geographical condition as justly as possible.

4 PROPOSED METHOD

4.1 Outline

In order to methodologically evaluate the well-formedness of world history essays in terms of the chronological and the geographical information, we proposed a scoring method based on the hypotheses described in Section 3. Note that the proposed method does not take into account the truth of the content. The fusion of our score and the content score measured by the ROUGE family, the Pyramid method, and others, is future work.

Figure 3 shows the outline of the proposed method. First, the input essay is segmented into HEs by punctuation marks. A HE is represented by a set of named entities extracted from the segment. Some named entities evoke the chronological and/or the geographical information. For example, "Napoleon Bonaparte" evokes the chronological information "from 15 August 1769 to 5 May 1821"
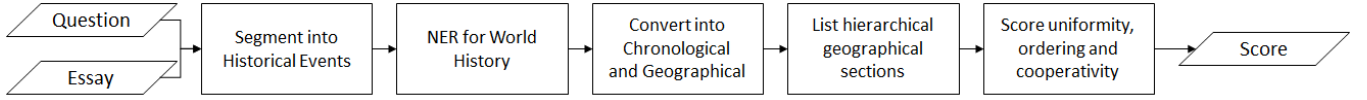
| Question | → | Segment into Historical Events | → | NER for World History | → | Convert into Chronological and Geographical | → | List hierarchical geographical sections | → | Score uniformity, ordering and cooperativity | → | Score |
| Essay | | | | | | | | | | | | |

Figure 3: The outline of the proposed method

and the geographical information "France." Because exam cram books cover such information, we constructed a database of world history terms based on the world history glossary published by Yamakawa Shuppan-sha.[4] Using the database, the named entities are converted into chronological and geographical information. Using both chronological and geographical information sets, the period and the range of the segment are respectively determined in the same way as that of the GS described in 3.4. They are regarded as the chronological and geographical information of the HE. Then, all hierarchical structures of GSs that can be gotten from the essay are listed. After scoring the HEs for each hierarchical structure, the maximum score is selected as the final score for the essay in order to select the most plausible hierarchical structure.

4.2 Scoring

GSs in a hierarchical structure are classified into terminal and non-terminal sections. A terminal section means an HE sequence without hierarchical structure, and likewise a non-terminal section can be divided into several GSs. We defined a non-terminal section corresponding to the essay as the root section. A GS s is defined as a paired HE sequence $E = (e_1, e_2, \cdots, e_m)$ and GS sequence $SS = (s_1, s_2, \cdots, s_n)$. If SS is an empty tuple, then the GS is a terminal section. HEs in a sub-GS are shared with the superordinate GS, and E of non-terminal sections are not empty. For a question, the chronological condition CC is defined as a pair of the beginning time bt and the ending time et, and the geographical condition GC is defined as a geographical entities set $\{g_1, g_2, \cdots, g_k\}$.

Based on the hypothesis (H2), the score sc for a GS to a question is recursively calculated by the following expressions.

$$sc(E, SS, CC, GC) = \begin{cases} sc_T(E, CC) \\ \quad \text{if it is a terminal section} \\ sc_N(E, SS, CC)sc_{GC}(E, GC) \\ \quad \text{if it is the root section} \\ sc_N(E, SS, CC) \\ \quad \text{otherwise} \end{cases} \quad (1)$$

$$sc_T(E, CC) = sc_{CO}(E)sc_{GO}(E)sc_{CC}(E, CC) \quad (2)$$

$$sc_N(E, SS, CC) = \frac{1}{|SS|}sc_{GU}(SS)sc_{QU}(SS)$$

$$\sum_{i=1}^{|SS|} sc(events(s_i), sections(s_i), CC, GC) \quad (3)$$

where $sc_{CO}()$ and $sc_{GO}()$ are functions to score the chronological ordering and the geographical ordering described in 3.3, $sc_{CC}()$ and $sc_{GC}()$ are functions to score the chronological cooperability and the geographical cooperability described in 3.4, $sc_{GU}()$ and $sc_{QU}()$ are respectively functions to score the geographical uniformity and the quantity uniformity described in 3.2, and $events(s)$ and $sections(s)$ are functions to return an HE sequence and a GS sequence included in a GS s, respectively. We designed the scoring

functions to be normalized into the range [0, 1], which are described in 4.2.1 to 4.2.3.

4.2.1 Ordering Score. Based on the hypothesis (H3), using the correlation between the describing order and the chronological order, the chronological ordering score sc_{CO} is calculated by the following expression.

$$sc_{CO}(E) = \frac{K - L}{K + L} \quad (4)$$

where K is the number of concordant pairs of HEs in E, and L is the number of discordant pairs. The expression (4) is the formula for the Kendall rank correlation coefficient. Based on the hypotheses (H6), when K and L are counted, pairs whose HEs are in the inclusion relation are excluded. For HEs in E, if the ranks in the describing order are completely concordant with the ranks in the chronological order, $sc_{CO}(E)$ returns 1.

For measuring the geographical distance in the hypothesis (H7), some sort of geographical knowledge base is required. However, available geographical databases such as the GeoNames[5] are insufficient to support the geographical entities of world history because of countries that no longer exists and other inconsistencies. Therefore, we constructed a geographic thesaurus specialized in world history by extracting and clustering all geographical entities from the world history textbook published by Tokyo Shoseki.[6] The geographical entities are hierarchically grouped into classes of continent, subregion of continent, country and city. Using the geographic thesaurus, the geographical ordering score sc_{GO} is calculated by the following expression.

$$sc_{GO}(E) = \frac{1}{geochange(E) + 1} \quad (5)$$

$$geochange(E) = \frac{1}{|E| - 1} \sum_{i=1}^{|E|-1} distance(range(e_i), range(e_{i+1})) \quad (6)$$

where $range(e)$ is a function to return a thesaurus node that is the nearest common node subsuming all geographical entities included in the HE e, and $distance(n_i, n_j)$ is a function to return the shortest distance between the thesaurus nodes n_i and n_j. If there is no change in the range of HEs in E, $sc_{GO}(E)$ returns 1.

4.2.2 Cooperability Score. Based on the hypothesis (H8), the chronological cooperability score sc_{CC} is calculated by the following expression.

$$sc_{CC}(E, CC) = \frac{overlap(period(E), CC)}{extend(period(E), CC)} \quad (7)$$

where $period(E)$ is a function to return a pair of the earliest time and the latest time in E, $overlap(P_1, P_2)$ is a function to return the length of the overlap period between P_1 and P_2, and $extend(P_1, P_2)$ is a function to return the length of the period between the earliest time and the latest time among P_1 and P_2. Note that $period()$ deals

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[4]http://www.yamakawa.co.jp/ (in Japanese)

[5]http://www.geonames.org/
[6]http://www.tokyo-shoseki.co.jp/ (in Japanese)

with the times that can determine the end of the period. If there are two periods of HEs "from 1900 A.D. to 1910 A.D." and "up to 1920 A.D.," $period()$ returns the period "from 1900 A.D. to 1920 A.D." although the later may be occurred before 1900 A.D. When the period of E is exactly overlapped the period of CC, $sc_{CC}(E, CC)$ returns 1.

Based on the hypothesis (H9), the geographical cooperability score sc_{GC} is calculated by the following expression.

$$sc_{GC}(E, GC) = \frac{2P(E, GC)R(E, GC)}{P(E, GC) + R(E, GC)} \tag{8}$$

$$P(E, GC) = \frac{subsumed(geoentities(E), GC)}{|geoentities(E)|} \tag{9}$$

$$R(E, GC) = \frac{subsuming(geoentities(E), GC)}{|GC|} \tag{10}$$

where $geoentities(E)$ is a function that returns a set of geographical entities included in E, $subsumed(G_1, G_2)$ is a function that returns the number of geographical entities of G_1 subsumed by geographical entities of G_2, and $subsuming(G_1, G_2)$ is a function that returns the number of geographical entities of G_2 subsuming geographical entities of G_1. The expression (8) is the harmonic mean of precision and recall between the geographical entity set of E and GC. If all geographical entities of E are subsumed under GC and all geographical entities of GC subsume at least one of the geographical entities of E, $sc_{GC}(E, GC)$ returns 1.

4.2.3 Uniformity Score. While there is always something described in a GS, the description does not always correspond to a particular category of the geographic thesaurus, such as a country. We used the standard deviation of the depth of category nodes in the geographic thesaurus for the geographical uniformity, while information entropy is used for the quantity uniformity. Based on the hypothesis (H4), the geographical uniformity score sc_{GU} is calculated by the following expression.

$$sc_{GU}(SS) = 1 - \frac{sd_{GU}(S)}{am_{GU}(SS)} \tag{11}$$

$$sd_{GU}(SS) = \sqrt{\frac{1}{|SS|} \sum_{i=1}^{|SS|} (depth(s_i) - am_{GU}(SS))^2} \tag{12}$$

$$am_{GU}(SS) = \frac{1}{|SS|} \sum_{i=1}^{|SS|} depth(s_i) \tag{13}$$

where $depth(s)$ is a function to return the distance between the thesaurus root node and the node corresponding to the range of s. When all depths the ranges of GSs in SS, $sc_{GU}(SS)$ returns 1.

Based on the hypothesis (H5), the quantity uniformity score sc_{QU} is calculated by the following expression.

$$sc_{QU}(SS) = \frac{-\sum_{i=1}^{|SS|} p(s_i, SS) \log_2 p(s_i, SS)}{\log_2 |SS|} \tag{14}$$

$$p(s, SS) = \frac{length(s)}{\sum_{i=1}^{|SS|} length(s_i)} \tag{15}$$

where $length(s)$ is a function to return the number of characters described in s. The expression (14) is the normalized formula for information entropy. When all numbers of characters in GSs of SS are equal, $sc_{QU}(SS)$ returns 1.

5 EXPERIMENTAL RESULT

Using all essays submitted to the QA Lab-2 Phase-1 and -3 [11], we compared the scores measured by the proposed method and the scores evaluated by human expert. Although the number of the essays is only 15, they are annotated with the marks granted and taken away besides the total score by a human expert. Note that the essays are mixed with essays answering 8 different questions. Basically the marks awarded take account of the correctness of the content, and the marks lost account for the ill-formedness. With this, we compared the scores to the method behind subtracting marks. Note that the lost marks are caused by not only chronological and geographical inconsistencies.

Figure 4 shows the scatter plot between the scores by our method and the subtracted marks. The two dots in the circle of Figure 4 are far apart. They represent the essays answering the same question, and the other dots are essays answering the other questions. The question of the two essays asks for an overview of Egyptian history since the birth of Egyptian civilization. The chronological condition is helpless to screen HEs chronologically, and the geographical condition is limited to Egypt - a relatively small region. In this case, almost all HEs satisfy the chronological condition, and the GS structure is flat, which means there is only a single (root) GS and there is no sub-GS. As a result, the method scores are extremely high as long as the essays describe the HEs in Egypt in chronological order. Except for two essays, the correlation coefficient was 0.21, which indicated a weak positive correlation. Taking into account that the marks subtracted include other causes than the chronological and geographical problems, the value seems to be fairly good. However, the sample size was small and there is much room for improvement of the method. We will conduct further research with a larger number of essays.

6 RELATED WORK

The linguistic well-formedness in the DUC workshop and the readability/fluency in the TAC Guided Summarization tasks were evaluated in terms of grammaticality, non-redundancy, referential clarity, focus, and 'structure and coherence'. Our measures are relative to the focus and 'structure and coherence'.

Although Barzilay et al. [2] and Okazaki et al. [9] researched the chronological ordering, they did not take account of geographical information. Buscaldi et al. [4] found that geography is related to semantic similarity, but they only aimed to measure semantic equivalence between two text snippets. Because Madanani et al. [7] only researched sentence ordering, the research only applied to the context of a short, domain-independent summarization. Bauer and Teufe [3] proposed the extended Pyramid method for timeline summarization, but they did not focus on the well-formedness. Although Wagner et al. [13] researched the well-formedness, they focused only on grammatical errors. Therefore, there is no research on a methodology for measuring the focus and the structure and coherence of world history essays in terms of the chronological and geographical information.
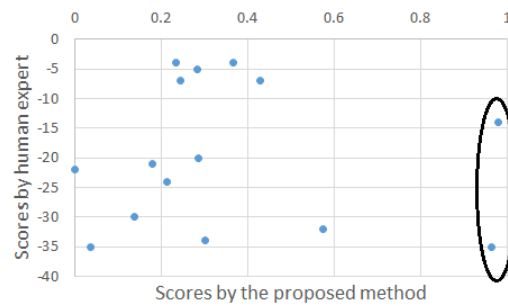
Figure 4: The scatter plot between the scores by the method and the scores by a human expert

7 CONCLUSION

For world history essays in Japanese university entrance exams, we proposed a method for measuring the uniformity, ordering and cooperability in terms of the chronological and the geographical information. The features of well-formedness are found by observing several model answer essays. From the experimental result, we found a weak positive correlation between the scores measured by our method and the scores estimated by a human expert in world history. The scoring functions of the method are based on simple concepts. We will investigate more appropriate functions in the future.

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