

From Single to Multi-document Summarization: A Prototype System and its Evaluation

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Abstract

NeATS is a multi-document summarization system that attempts to extract relevant or interesting portions from a set of documents about some topic and present them in coherent order. NeATS is among the best performers in the large scale summarization evaluation DUC 2001.

1 Introduction

In recent years, text summarization has been enjoying a period of revival. Two workshops on Automatic Summarization were held in 2000 and 2001. However, the area is still being fleshed out: most past efforts have focused only on single-document summarization (Mani 2000), and no standard test sets and large scale evaluations have been reported or made available to the English-speaking research community except the TIPSTER SUMMAC Text Summarization evaluation (Mani et al. 1998).

To address these issues, the Document Understanding Conference (DUC) sponsored by the National Institute of Standards and Technology (NIST) started in 2001 in the United States. The Text Summarization Challenge (TSC) task under the NTCIR (NII-NACSIS Test Collection for IR Systems) project started in 2000 in Japan. DUC and TSC both aim to compile standard training and test collections that can be shared among researchers and to provide common and large scale evaluations in single and multiple document summarization for their participants.

In this paper we describe a multi-document summarization system NeATS. It attempts to extract relevant or interesting portions from a set of documents about some topic and present

them in coherent order. We outline the NeATS system and describe how it performs content selection, filtering, and presentation in Section 2. Section 3 gives a brief overview of the evaluation procedure used in DUC-2001 (DUC 2001). Section 4 discusses evaluation metrics, and Section 5 the results. We conclude with future directions.

2 NeATS

NeATS is an extraction-based multi-document summarization system. It leverages techniques proved effective in single document summarization such as: term frequency (Luhn 1969), sentence position (Lin and Hovy 1997), stigma words (Edmundson 1969), and a simplified version of MMR (Goldstein et al. 1999) to select and filter content. To improve topic coverage and readability, it uses term clustering, a ‘buddy system’ of paired sentences, and explicit time annotation.

Most of the techniques adopted by NeATS are not new. However, applying them in the proper places to summarize multiple documents and evaluating the results on large scale common tasks are new.

Given an input of a collection of sets of newspaper articles, NeATS generates summaries in three stages: content selection, filtering, and presentation. We describe each stage in the following sections.

2.1 Content Selection

The goal of content selection is to identify important concepts mentioned in a document collection. For example, *AA flight 11*, *AA flight 77*, *UA flight 173*, *UA flight 93*, *New York*, *World Trade Center*, *Twin Towers*, *Osama bin Laden*, and *al-Qaida* are key concepts for a document collection about the September 11 terrorist attacks in the US.

Rank	Unigram	(-2 λ)	Bigram	(-2 λ)	Trigram	(-2 λ)
1	Slovenia	319.48	federal army	21.27	Slovenia central bank	5.80
2	Yugoslavia	159.55	Slovenia Croatia	19.33	minister foreign affairs	5.80
3	Slovene	87.27	Milan Kucan	17.40	unallocated federal debt	5.80
4	Croatia	79.48	European Community	13.53	Drnovsek prime minister	3.86
5	Slovenian	67.82	foreign exchange	13.53	European Community countries	3.86

Figure 2. Top 5 unigram, bigram, and trigram concepts for topic "Slovenia Secession from Yugoslavia".

```

n1
(:SURF " WEBCL -SUMM MARIZ ER-KU CAN"
:CAT S- NP
:CLASS I-EN- WEBCL -SIGN ATURE -KUCAN
:LEX 0. 6363 63636 36363 6
:SUBS
(( (KUCAN-0)
(:SURF " Milan Kucan"
:CAT S- NP
:CLASS I-EN- WEBCL -SIGN ATURE -KUCAN
:LEX 0. 63636 36363 63636
:SUBS
((( KUCAN -1)
(:SURF " Kucan"
:CAT S- NP
:CLASS I-EN- WEBCL -SIGN ATURE -KUCAN
:LEX 0. 63636 36363 63636 )))
(( KUCAN -2)
(:SURF " Milan "
:CAT S- NP
:CLASS I-EN- WEBCL -SIGN ATURE -KUCAN
:LEX 0. 63636 36363 63636 ))))) )

```

Figure 1. Sample key concept structure.

In a key step for locating important sentences, NeATS computes the likelihood ratio λ (Dunning, 1993) to identify key concepts in unigrams, bigrams, and trigrams¹, using the on- topic document collection as the relevant set and the off-topic document collection as the irrelevant set. Figure 1 shows the top 5 concepts with their relevancy scores (-2 λ) for the topic "Slovenia Secession from Yugoslavia" in the DUC-2001 test collection. This is similar to the idea of topic signature introduced in (Lin and Hovy 2000).

With the individual key concepts available, we proceed to cluster these concepts in order to identify major subtopics within the main topic. Clusters are formed through strict lexical connection. For example, *Milan* and *Kucan* are grouped as "Milan Kucan" since "Milan Kucan" is a key bigram concept; while *Croatia*, *Yugoslavia*, *Slovenia*, *republic*, and are joined due to the connections as follows:

- *Slovenia Croatia*
- *Croatia Slovenia*
- *Yugoslavia Slovenia*
- *republic Slovenia*

¹ Closed class words (*of*, *in*, *and*, *are*, and so on) were ignored in constructing unigrams, bigrams and trigrams.

- *Croatia republic*

Each sentence in the document set is then ranked, using the key concept structures. An example is shown in Figure 2. The ranking algorithm rewards most specific concepts first; for example, a sentence containing "Milan Kucan" has a higher score than a sentence contains only either *Milan* or *Kucan*. A sentence containing both *Milan* and *Kucan* but not in consecutive order gets a lower score too. This ranking algorithm performs relatively well, but it also results in many ties. Therefore, it is necessary to apply some filtering mechanism to maintain a reasonably sized sentence pool for final presentation.

2.2 Content Filtering

NeATS uses three different filters: sentence position, stigma words, and maximum marginal relevancy.

2.2.1 Sentence Position

Sentence position has been used as a good important content filter since the late 60s (Edmundson 1969). It was also used as a baseline in a preliminary multi-document summarization study by Marcu and Gerber (2001) with relatively good results. We apply a simple sentence filter that only retains the lead 10 sentences.

2.2.2 Stigma Words

Some sentences start with

- conjunctions (e.g., *but*, *although*, *however*),
- the verb *say* and its derivatives,
- quotation marks,
- pronouns such as *he*, *she*, and *they*,

and usually cause discontinuity in summaries.

Since we do not use discourse level selection criteria à la (Marcu 1999), we simply reduce the scores of these sentences to avoid including them in short summaries.

2.2.3 Maximum Marginal Relevancy

```
<multi size="50" docset="d50i">
AP891210-0079 1 (32.20) (12/10/89) America's 1988 drought captured attention everywhere, but especially in
Washington where politicians pushed through the largest disaster relief measure in U.S. history.
AP891213-0004 1 (34.60) (12/13/89) The drought of 1988 hit ...
</multi>
<multi size="100" docset="d50i">
AP891210-0079 1 (32.20) (12/10/89) America's 1988 drought captured attention everywhere, but especially in
Washington where politicians pushed through the largest disaster relief measure in U.S. history.
AP891210-0079 3 (41.18) (12/10/89) The record $3.9 billion drought relief program of 1988, hailed as
salvation for small farmers devastated by a brutal dry spell, became much more _ an unexpected, election-
year windfall for thousands of farmers who collected millions of dollars for nature's normal quirks.
AP891213-0004 1 (34.60) (12/13/89) The drought of 1988 hit ...
</multi>
```

Figure 3. 50 and 100 word summaries for topic "US Drought of 1988".

The content selection and filtering methods described in the previous section only concern individual sentences. They do not consider the redundancy issue when two top ranked sentences refer to similar things. To address the problem, we use a simplified version of CMU's MMR (Goldstein et al. 1999) algorithm. A sentence is added to the summary if and only if its content has less than X percent overlap with the summary. The overlap ratio is computed using simple stemmed word overlap and the threshold X is set empirically.

2.3 Content Presentation

NeATS so far only considers features pertaining to individual sentences. As we mentioned in Section 2.2.2, we can demote some sentences containing stigma words to improve the cohesion and coherence of summaries. However, we still face two problems: definite noun phrases and events spread along an extended timeline. We describe these problems and our solutions in the following sections.

2.3.1 A Buddy System of Paired Sentences

The problem of definite noun phrases can be illustrated in Figure 3. These sentences are from documents of the DUC-2001 topic *US Drought of 1988*. According to pure sentence scores, sentence 3 of document AP891210-0079 has a higher score (34.60) than sentence 1 (32.20) and should be included in the shorter summary (size="50"). However, if we select sentence 3 without also including sentence 1, the definite noun phrase "*The record \$3.9 billion drought relief program of 1988*" seems to come without any context. To remedy this problem, we introduce a buddy system to improve cohesion and coherence. Each sentence is paired with a suitable introductory sentence unless it is already an introductory

sentence. In DUC-2001 we simply used the first sentence of its document. This assumes lead sentences provide introduction and context information about what is coming next.

2.3.2 Time Annotation and Sequence

One main problem in multi-document summarization is that documents in a collection might span an extended time period. For example, the DUC-2001 topic "*Slovenia Secession from Yugoslavia*" contains 11 documents dated from 1988 to 1994, from 5 different sources². Although a source document for single-document summarization might contain information collected across an extended time frame and from multiple sources, the author at least would synchronize them and present them in a coherent order. In multi-document summarization, a date expression such as *Monday* occurring in two different documents might mean the same date or different dates. For example, sentences in the 100 word summary shown in Figure 4 come from 3 main time periods, 1990, 1991, and 1994. If no absolute time references are given, the summary might mislead the reader to think that all the events mentioned in the four summary sentences occurred in a single week. Therefore, time disambiguation and normalization are very important in multi-document summarization. As the first attempt, we use publication dates as reference points and compute actual dates for the following date expressions:

- weekdays (*Sunday, Monday*, etc);
- (*past | next | coming*) + weekdays;
- *today, yesterday, last night*.

We then order the summary sentences in their chronological order. Figure 4 shows an

² Sources include Associated Press, Foreign Broadcast Information Service, Financial Times, San Jose Mercury News, and Wall Street Journal.

```
<multi size="100" docset="d45h">
AP900625-0160 1 (26.60) (06/25/90) The republic of Slovenia plans to begin work on a constitution
that will give it full sovereignty within a new Yugoslav confederation, the state Tanjug news agency
reported Monday (06/25/90).
WSJ910628-0109 3 (9.48) (06/28/91) On Wednesday (06/26/91), the Slovene soldiers manning this border
post raised a new flag to mark Slovenia's independence from Yugoslavia.
WSJ910628-0109 5 (53.77) (06/28/91) Less than two days after Slovenia and Croatia, two of Yugoslavia's
six republics, unilaterally seceded from the nation, the federal government in Belgrade mobilized
troops to regain control.
FBIS3-30788 2 (49.14) (02/09/94) In the view of Yugoslav diplomats, the normalization of relations
between Slovenia and the Federal Republic of Yugoslavia will certainly be a strenuous and long-term
project.
</multi>
```

Figure 4. 100 word summary with explicit time annotation.

example 100 words summary with time annotations. Each sentence is marked with its publication date and a reference date (MM/DD/YY) is inserted after every date expression.

3 DUC 2001

Before we present our results, we describe the corpus and evaluation procedures of the Document Understanding Conference 2001 (DUC 2001).

DUC is a new evaluation series supported by NIST under TIDES, to further progress in summarization and enable researchers to participate in large-scale experiments. There were three tasks in 2001:

- (1) Fully automatic summarization of a single document.
- (2) Fully automatic summarization of multiple documents: given a set of document on a single subject, participants were required to create 4 generic summaries of the entire set with approximately 50, 100, 200, and 400 words. 30 document sets of approximately 10 documents each were provided with their 50, 100, 200, and 400 human written summaries for training (training set) and another 30 unseen sets were used for testing (test set).
- (3) Exploratory summarization: participants were encouraged to investigate alternative approaches in summarization and report their results.

NeATS participated only in the fully automatic multi-document summarization task. A total of 12 systems participated in that task.

The training data were distributed in early March of 2001 and the test data were distributed in mid-June of 2001. Results were submitted to NIST for evaluation by July 1st.

3.1 Evaluation Procedures

NIST assessors who created the ‘ideal’ written summaries did pairwise comparisons of their summaries to the system-generated summaries, other assessors’ summaries, and baseline summaries. In addition, two baseline summaries were created automatically as reference points. The first baseline, *lead baseline*, took the first 50, 100, 200, and 400 words in the last document in the collection. The second baseline, *coverage baseline*, took the first sentence in the first document, the first sentence in the second document and so on until it had a summary of 50, 100, 200, or 400 words.

3.2 Summary Evaluation Environment

NIST used the Summary Evaluation Environment (SEE) 2.0 developed by one of the authors (Lin 2001) to support its human evaluation process. Using SEE, the assessors evaluated the quality of the system’s text (the peer text) as compared to an ideal (the model text). The two texts were broken into lists of units and displayed in separate windows. In DUC-2001 the sentence was used as the smallest unit of evaluation.

SEE 2.0 provides interfaces for assessors to judge the quality of summaries in grammatically³, cohesion⁴, and coherence⁵ at five different levels: *all*, *most*, *some*, *hardly any*, or *none*. It also allows assessors to step through each model unit, mark all system units sharing content with the current model unit, and specify that the marked system units

³ Does a summary follow the rule of English grammatical rules independent of its content?

⁴ Do sentences in a summary fit in with their surrounding sentences?

⁵ Is the content of a summary expressed and organized in an effective way?

express *all*, *most*, *some* or *hardly any* of the content of the current model unit.

4 Evaluation Metrics

One goal of DUC-2001 was to debug the evaluation procedures and identify stable metrics that could serve as common reference points. NIST did not define any official performance metric in DUC-2001. It released the raw evaluation results to DUC-2001 participants and encouraged them to propose metrics that would help progress the field.

4.1.1 Recall, Coverage, Retention and Weighted Retention

Recall at different compression ratios has been used in summarization research (Mani 2001) to measure how well an automatic system retains important content of original documents. Assume we have a system summary S_s and a model summary S_m . The number of sentences occurring in both S_s and S_m is N_o , the number of sentences in S_s is N_s , and the number of sentences in S_m is N_m . Recall is defined as N_o/N_m . The Compression Ratio is defined as the length of a summary (by words or sentences) divided by the length of its original document. DUC-2001 set the compression lengths to 50, 100, 200, and 400 words for the multi-document summarization task. However, applying recall in DUC-2001 without modification is not appropriate because:

1. Multiple system units contribute to multiple model units.
2. S_s and S_m do not exactly overlap.
3. Overlap judgment is not binary.

For example, in an evaluation session an assessor judged system units S1.1 and S10.4 as sharing *some* content with model unit M2.2. Unit S1.1 says “*Thousands of people are feared dead*” and unit M2.2 says “*3,000 and perhaps ... 5,000 people have been killed*”. Are “thousands” equivalent to “3,000 to 5,000” or not? Unit S10.4 indicates it was an “*earthquake of magnitude 6.9*” and unit M2.2 says it was “*an earthquake measuring 6.9 on the Richter scale*”. Both of them report a “6.9” earthquake. But the second part of system unit S10.4, “*in an area so isolated...*”, seems to share some content with model unit M4.4 “*the quake was centered in a remote mountainous area*”. Are these two equivalent?

This example highlights the difficulty of judging the content coverage of system summaries against model summaries and the inadequacy of using recall as defined.

As we mentioned earlier, NIST assessors not only marked the sharing relations among system units (SU) and model units (MU), they also indicated the degree of match, i.e., *all*, *most*, *some*, *hardly any*, or *none*. This enables us to compute *weighted recall*.

Different versions of weighted recall were proposed by DUC-2001 participants. McKeown et al. (2001) treated the completeness of coverage as threshold: 4 for *all*, 3 for *most* and above, 2 for *some* and above, and 1 for *hardly any* and above. They then proceeded to compare system performances at different threshold levels. They defined recall at threshold t , $Recall_t$, as follows:

$$\frac{\text{Number of MUs marked at or above } t}{\text{Total number of MUs in the model summary}}$$

We used the completeness of coverage as coverage score, C , instead of threshold: 1 for *all*, 3/4 for *most*, 1/2 for *some*, and 1/4 for *hardly any*, 0 for *none*. To avoid confusion with the recall used in information retrieval, we call our metric weighted retention, $Retention_w$, and define it as follows:

$$\frac{(\text{Number of MUs marked}) \bullet C}{\text{Total number of MUs in the model summary}}$$

if we ignore C and set it always to 1, we obtain an unweighted retention, $Retention_1$. We used $Retention_1$ in our evaluation to illustrate that relative system performance changes when different evaluation metrics are chosen. Therefore, it is important to have common and agreed upon metrics to facilitate large scale evaluation efforts.

4.1.2 Precision and Pseudo Precision

Precision is also a common measure. Borrowed from information retrieval research, precision is used to measure how effectively a system generates good summary sentences. It is defined as N_o/N_s . Precision in a fixed length summary output is equal to recall since $N_s = N_m$. However, due to the three reasons stated at the beginning of the previous section, no straightforward computation of the traditional precision is available in DUC-2001.

SYS	Pp All	R1 All	Rw All	Pp 400	R1 400	Rw 400	Pp 200	R1 200	Rw 200	Pp 100	R1 100	Rw 100	Pp 50	R1 50	Rw 50
HM	58.71%	53.00%	28.81%	59.33%	52.95%	33.23%	59.91%	57.23%	33.82%	58.73%	54.67%	27.54%	56.87%	47.16%	2162%
T	48.96%	35.53%(3)	18.48%(1)	56.51%(3)	38.50%(3)	25.12%(1)	53.85%(3)	35.62%	21.37%(1)	43.53%	32.82%(3)	14.28%(3)	41.95%	35.17%(2)	13.89%(2)
N*	58.72%(1)	37.52%(2)	17.92%(2)	61.01%(1)	41.21%(1)	23.90%(2)	63.34%(1)	38.21%(3)	21.30%(2)	58.79%(1)	36.34%(2)	16.44%(2)	51.72%(1)	34.31%(3)	10.98%(3)
Y	41.51%	41.58%(1)	17.78%(3)	49.78%	38.72%(2)	20.04%	43.63%	39.90%(1)	16.86%	34.75%	43.27%(1)	18.39%(1)	37.88%	44.43%(1)	15.55%(1)
P	49.56%	33.94%	15.78%	57.21%(2)	37.76%	22.18%(3)	51.45%	37.49%	19.40%	46.47%	31.64%	13.92%	43.10%	28.85%	9.09%
L	51.47%(3)	33.67%	15.49%	52.62%	36.34%	21.80%	53.51%	36.87%	18.34%	48.62%(3)	29.00%	12.54%	51.15%(2)	32.47%	9.90%
B2	47.27%	30.98%	14.56%	60.99%	33.51%	18.35%	49.89%	33.27%	17.72%	47.18%	29.48%	14.96%	31.03%	27.64%	8.02%
S	52.53%(2)	30.52%	12.89%	55.55%	36.83%	20.35%	58.12%(2)	38.70%(2)	19.93%(3)	49.70%(2)	26.81%	10.72%	46.43%(3)	19.23%	4.04%
M	43.39%	27.27%	11.32%	54.78%	33.81%	19.86%	45.59%	27.80%	13.27%	41.89%	23.40%	9.13%	31.30%	24.07%	5.05%
R	41.86%	27.63%	11.19%	48.63%	24.80%	12.15%	43.96%	31.28%	15.17%	38.35%	27.61%	11.46%	36.49%	26.84%	6.17%
O	43.76%	25.87%	11.19%	50.73%	27.53%	15.76%	42.94%	26.80%	13.07%	40.55%	25.13%	9.36%	40.80%	24.02%	7.03%
Z	37.98%	23.21%	8.99%	47.51%	31.17%	17.38%	46.76%	25.65%	12.83%	28.91%	17.29%	5.45%	28.74%	18.74%	3.23%
B1	32.92%	18.86%	7.45%	33.48%	17.58%	9.98%	43.13%	18.60%	8.65%	30.23%	17.42%	6.05%	24.83%	21.84%	4.20%
W	30.08%	20.38%	6.78%	38.14%	25.89%	12.10%	26.86%	21.01%	7.93%	28.31%	19.15%	5.36%	27.01%	15.46%	3.21%
U	23.88%	21.38%	6.57%	31.49%	29.76%	13.17%	24.20%	22.64%	8.49%	19.13%	17.54%	3.77%	20.69%	15.57%	3.04%

Table 1. Pseudo precision, unweighted retention, and weighted retention for all summary lengths: overall average, 400, 200, 100, and 50 words.

If we count the number of model units that are marked as good summary units and are selected by systems, and use the number of model units in various summary lengths as the sample space, we obtain a precision metric equal to $Retention_1$. Alternatively, we can count how many unique system units share content with model units and use the total number of system units as the sample space. We define this as pseudo precision, $Precision_p$, as follows:

$$Precision_p = \frac{\text{Number of SUs marked}}{\text{Total number of SUs in the system summary}}$$

Most of the participants in DUC-2001 reported their pseudo precision figures.

5 Results and Discussion

We present the performance of NeATS in DUC-2001 in content and quality measures.

5.1 Content

With respect to content, we computed $Retention_1$, $Retention_w$, and $Precision_p$ using the formulas defined in the previous section. The scores are shown in Table 1 (overall average and per size). Analyzing all systems' results according to these, we made the following observations.

(1) NeATS (system N) is consistently ranked among the top 3 in average and per size $Retention_1$ and $Retention_w$.

(2) NeATS's performance for averaged pseudo precision equals human's at about 58% ($P_{p\text{ all}}$).

(3) The performance in weighted retention is really low. Even humans⁶ score only 29% ($R_{w\text{ all}}$). This indicates low inter-human agreement (which we take to reflect the undefinedness of the 'generic summary' task). However, the unweighted retention of humans is 53%. This suggests assessors did write something similar in their summaries but not exactly the same; once again illustrating the difficulty of summarization evaluation.

(4) Despite the low inter-human agreement, humans score better than any system. They outscore the nearest system by about 11% in averaged unweighted retention ($R_{1\text{ all}}$: 53% vs. 42%) and weighted retention ($R_{w\text{ all}}$: 29% vs. 18%). There is obviously still considerable room for systems to improve.

(5) System performances are separated into two major groups by baseline 2 (B2: coverage baseline) in averaged weighted retention. This confirms that lead sentences are good summary sentence candidates and that one does need to cover all documents in a topic to achieve reasonable performance in multi-document summarization. NeATS's strategies of filtering sentences by position and adding lead sentences to set context are proved effective.

(6) Different metrics result in different performance rankings. This is demonstrated by the top 3 systems T, N, and Y. If we use the averaged unweighted retention ($R_{1\text{ all}}$), Y is

⁶ NIST assessors wrote two separate summaries per topic. One was used to judge all system summaries and the two baselines. The other was used to determine the (potential) upper bound.

SYS	Grammar	Cohesion	Coherence
Human	3.74	2.74	3.19
B1	3.18	2.63	2.8
B2	3.26	1.71	1.65
L	3.72	1.83	1.9
M	3.54	2.18	2.4
N*	3.65	2	2.22
O	3.78	2.15	2.33
P	3.67	1.93	2.17
R	3.6	2.16	2.45
S	3.67	1.93	2.04
T	3.51	2.34	2.61
U	3.28	1.31	1.11
W	3.13	1.48	1.28
Y	2.45	1.73	1.77
Z	3.28	1.8	1.94

Table 2. Averaged grammaticality, cohesion, and coherence over all summary sizes.

the best, followed by N, and then T; if we choose averaged weighted retention (R_w all), T is the best, followed by N, and then Y. The reversal of T and Y due to different metrics demonstrates the importance of common agreed upon metrics. We believe that metrics have to take coverage score (C , Section 4.1.1) into consideration to be reasonable since most of the content sharing among system units and model units is partial. The recall at threshold t , $Recall_t$ (Section 4.1.1), proposed by (McKeown et al. 2001), is a good example. In their evaluation, NeATS ranked second at $t=1$, 3, 4 and first at $t=2$.

(7) According to Table 1, NeATS performed better on longer summaries (400 and 200 words) based on weighted retention than it did on shorter ones. This is the result of the sentence extraction-based nature of NeATS. We expect that systems that use syntax-based algorithms to compress their output will thereby gain more space to include additional important material. For example, System Y was the best in shorter summaries. Its 100- and 50-word summaries contain only important headlines. The results confirm this is a very effective strategy in composing short summaries. However, the quality of the summaries suffered because of the unconventional syntactic structure of news headlines (Table 2).

5.2 Quality

Table 2 shows the macro-averaged scores for the humans, two baselines, and 12 systems. We assign a score of 4 to *all*, 3 to *most*, 2 to *some*, 1 to *hardly any*, and 0 to *none*. The value assignment is for convenience of

computing averages, since it is more appropriate to treat these measures as stepped values instead of continuous ones. With this in mind, we have the following observations.

(1) Most systems scored well in grammaticality. This is not a surprise since most of the participants extracted sentences as summaries.

But no system or human scored perfect in grammaticality. This might be due to the artifact of cutting sentences at the 50, 100, 200, and 400 words boundaries. Only system Y scored lower than 3, which reflects its headline inclusion strategy.

(2) When it came to the measure for cohesion the results are confusing. If even the human-made summaries score only 2.74 out of 4, it is unclear what this category means, or how the assessors arrived at these scores. However, the humans and baseline 1 (lead baseline) did score in the upper range of 2 to 3 and all others had scores lower than 2.5. Some of the systems (including B2) fell into the range of 1 to 2 meaning some or hardly any cohesion.

The lead baseline (B1), taking the first 50, 100, 200, 400 words from the last document of a topic, did well. On the contrary, the coverage baseline (B2) did poorly. This indicates the difficulty of fitting sentences from different documents together. Even selecting continuous sentences from the same document (B1) seems not to work well. We need to define this metric more clearly and improve the capabilities of systems in this respect.

(3) Coherence scores roughly track cohesion scores. Most systems did better in coherence than in cohesion. The human is the only one scoring above 3. Again the room for improvement is abundant.

(4) NeATS did not fare badly in quality measures. It was in the same categories as other top performers: grammaticality is between *most* and *all*, cohesion, *some* and *most*, and coherence, *some* and *most*. This indicates the strategies employed by NeATS (stigma word filtering, adding lead sentence, and time annotation) worked to some extent but left room for improvement.

6 Conclusions

We described a multi-document summarization system, NeATS, and its evaluation in DUC-2001. We were encouraged by the content and readability of the results. As a prototype system, NeATS deliberately used simple methods guided by a few principles:

- Extracting important concepts based on reliable statistics.
- Filtering sentences by their positions and stigma words.
- Reducing redundancy using MMR.
- Presenting summary sentences in their chronological order with time annotations.

These simple principles worked effectively. However, the simplicity of the system also lends itself to further improvements. We would like to apply some compression techniques or use linguistic units smaller than sentences to improve our retention score. The fact that NeATS performed as well as the human in pseudo precision but did less well in retention indicates its summaries might include good but duplicated information. Working with sub-sentence units should help.

To improve NeATS's capability in content selection, we have started to parse sentences containing key unigram, bigram, and trigram concepts to identify their relations within their concept clusters.

To enhance cohesion and coherence, we are looking into incorporating discourse processing techniques (Marcu 1999) or Radev and McKeown's (1998) summary operators.

We are analyzing the DUC evaluation scores in the hope of suggesting improved and more stable metrics.

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