Overview of the IWSLT 2008 Evaluation Campaign

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Abstract
This paper gives an overview of the evaluation campaign results of the International Workshop on Spoken Language Translation (IWSLT) 2008. In this workshop, we focused on the translation of spontaneous speech recorded in a real situation and the feasibility of pivot-language-based translation approaches. The translation directions were English into Chinese and vice versa for the Challenge Task, Chinese into English and English into Spanish for the Pivot Task, and Arabic, Chinese, Spanish into English for the standard BTEC Task. In total, 19 research groups building 58 MT engines participated in this year’s event. Automatic and subjective evaluations were carried out in order to investigate the impact of spontaneity aspects of field data experiments on automatic speech recognition (ASR) and machine translation (MT) system performance as well as the robustness of state-of-the-art MT systems towards speech-to-speech translation in real environments.

1. Introduction
The International Workshop on Spoken Language Translation (IWSLT) is a yearly, open evaluation campaign for spoken language translation organized by the Consortium for Speech Translation Advanced Research (C-STAR). IWSLT’s evaluations are not competition-oriented, but their goal is to foster cooperative work and scientific exchange. In this respect, IWSLT proposes challenging research tasks and an open experimental infrastructure for the scientific community working on spoken and written language translation.

Previous IWSLT workshops focused on the establishment of evaluation metrics for multilingual speech-to-speech translation, the translation of automatic speech recognition results from read-speech and spontaneous-speech input, and dialog conversations [1, 2, 3, 4].

The focus of this year’s evaluation campaign was the translation of spontaneous speech recorded in a real situation. Foreign travelers were provided with a state-of-the-art speech-to-speech translation hand-held device and were asked to carry-out specific tourism-related tasks (e.g., buying entrance tickets) using the device to communicate with local staff. Speech data was collected for 50 English and 50 Chinese travelers at 5 different locations, each carrying out 3-4 tasks. For the Challenge Task, IWSLT participants translated the Chinese/English output of the automatic speech recognizers (lattice, N/1BEST) into English/Chinese, respectively.

Another innovative aspect of this year’s edition was the investigation of the feasibility of pivot-language-based translation approaches. In the Pivot Task, participants were provided with read-speech recordings (lattice, N/1BEST) of Chinese utterances from the travel domain and had to apply Chinese-English and English-Spanish systems to produce the Spanish output. Like in previous IWSLT events, a standard BTEC Task, i.e. the translation of read-speech recordings (lattice, N/1BEST) and correct recognition results (text) of frequently used utterances in the travel domain, was also carried out for the translation of Chinese and Arabic into English as well as Chinese (directly) into Spanish.

Continuing the efforts started in 2007 to provide a list of linguistic resources and tools that can be shared by the participants, we asked that each participant send us information about non-proprietary resources used in the development of this year’s submission so that other groups could also utilize these resources for the various tasks. It should be noted though, that participants did not have to provide resources directly. Nor were participants required to provide resources that they have acquired elsewhere and had then modified in some way (i.e. cleaned, corrected, or enhanced). In this latter example, a group provided a reference or link to the original provider or creator. Moreover, acceptable resources should be affordable by most research groups (publicly available monolingual or bilingual corpora, LDC data, etc.). In contrast, participants were not allowed to train or tune their systems on privately developed linguistic resources and/or corpora, NIST or LDC data which require participation in an evaluation campaign like GALE or NIST-MT, or publicly available linguistic resources which require high licensing fees. In addition, the use of resources supplied for other data tracks and previous IWSLT evaluation campaigns was also not allowed.

In total, 19 research groups participated in this year’s evaluation campaign. A total of 58 MT engines were built...
to cover six different data tracks. The translation quality of all primary run submissions was evaluated using automatic evaluation metrics (BLEU [5], METEOR [6]) and a subjective evaluation metric that ranks each whole sentence translation from best to worst relative to the other choices [7]. In addition, human assessments of fluency and adequacy [8] were carried out for four selected MT system outputs for each of the data tracks. Based on the evaluation results, the impact of the spontaneity aspects of speech in real situations on the ASR and MT system performance as well as the robustness of state-of-the-art MT systems against speech recognition errors were investigated.

2. IWSLT 2008 Evaluation Campaign

This year’s IWSLT evaluation campaign took place in the period of April-July 2008 and featured six different data track conditions:

| Table 1: Data Tracks |
|----------------------|
| **Task**             | **Translation Direction** | **Participants** |
| Challenge            | CT<sub>EC</sub>            | 7               |
| English-Chinese      | CT<sub>EC</sub>            | 7               |
| Chinese-English      | CT<sub>EC</sub>            | 11              |
| Arabic-English       | BT<sub>AE</sub>            | 10              |
| Chinese-English      | BT<sub>CE</sub>            | 14              |
| Chinese-Spanish      | BT<sub>CS</sub>            | 8               |
| Pivot                | PV<sub>CS</sub>            | 8               |

In total, 19 research groups from all over the world participated in the event, producing a total of 58 machine translation engines for the above six data tracks. Information on the organisations, the utilized translation systems, and data track participation is summarized in Appendix A. Most participants used statistical machine translation (SMT) systems. However, one example-based MT (EBMT) system and various hybrid approaches combining SMT engines with EBMT systems or rule-based (RBMT) systems were also exploited.

For training purposes, a spoken language corpus described in Section 2.1 was provided to all participating research groups. In addition, the participants were free to use additional resources that could be shared among the participants. The supplied resources of IWSLT 2008 were released one month ahead of the official run submissions period. The official run submission period was limited to five days. Run submission was carried out via email to the organizers whereby multiple runs were permitted. However, the participant had to specify which run should be treated as primary (evaluation using human assessments and automatic metrics) or contrastive (automatic evaluation only). In total, 58 primary runs and 101 contrastive runs were submitted. After the official run submission period, the organizers set-up an online evaluation server that could be used by the participants to carry out additional experiments on the evaluation testset.

The schedule of the evaluation campaign is summarized in Table 2.

| Table 2: Evaluation Campaign Schedule |
|---------------------------------------|
| **Event**                             | **Date** |
| Training Corpus Release                | June 2, 2008 |
| Development Corpus Release             | June 2, 2008 |
| Evaluation Corpus Release              | June 30, 2008 |
| Result Submission Due                  | July 4, 2008 |

2.1. IWSLT 2008 Spoken Language Corpus

The IWSLT 2008 evaluation campaign was carried out using a multilingual spoken language corpus. The Basic Travel Expression Corpus (BTEC) contains tourism-related sentences similar to those that are usually found in phrase books for tourists traveling abroad [9]. Parts of this corpus were already used in previous IWSLT evaluation campaigns [1, 2, 3, 4]. In addition to a sentence-aligned training corpus, the evaluation data sets of previous workshops including multiple reference translations were provided to the participants as a development corpus.

The evaluation data sets of IWSLT 2008 consisted of two different types of data. For the Challenge Task, machine-mediated conversational speech was recorded in a real situation. For the Pivot Task and the BTEC Task, read-speech recordings of randomly selected sentences from parts of the BTEC corpus reserved for evaluation purposes were used.

ASR engines provided by the C-STAR partners were applied to the above speech data sets and produced word lattices from which NBEST/IBEST lists were extracted automatically using publicly available tools. Participants were free to choose the ASR output condition that best suited their machine translation technology for the input of the respective MT engine. In addition, the cleaned transcripts of the speech recordings, i.e., the correct recognition results (CRR), were also given to all participants for translation. Word segmentations according to the output of the ASR engines were also provided for all supplied resources.

2.1.1. Supplied Resources

For this year’s evaluation campaign, parts of the Arabic (A), Chinese (C), English (E), and Spanish (S) subsets of the BTEC corpus were used. The participants were supplied with a training corpus of 20K sentence pairs which covered the same sentence IDs for CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>AE</sub>, BT<sub>CE</sub>, and the English-Spanish pair (PV<sub>ES</sub>) of the PV<sub>CS</sub> training corpus. In order to avoid a trilingual scenario for the Pivot Task, a separate set of 20K sentence pairs were selected for the Chinese-English pair (PV<sub>CE</sub>) of PV<sub>CS</sub>.

In order to optimize and evaluate their translation engines on in-domain data, the testsets of previous IWSLT evaluation...
campaigns as well as one third of the newly collected spontaneous data sets of the Challenge Task were provided to the participants together with up to 16 reference translations for each of the target languages.

Concerning the evaluation data sets of the Challenge Task of IWSLT 2008, machine-mediated conversational speech was recorded in a real situation. Foreign travelers were provided with a state-of-the-art speech-to-speech translation handheld device and were asked to carry out specific tourism-related tasks (e.g., buying entrance tickets) by using the device to communicate with local staff. In total, speech data of 50 English and 50 Chinese travelers were released as the evaluation data set of CT_ECE and CT_EAE, respectively. Recordings were done at 5 different locations where each speaker carried out 3-4 tasks.

The evaluation data sets of the BTEC Task and the Pivot Task consisted of read-speech recordings whereby the source language texts were read aloud by 10 native speakers. The reference translations for BTEC and BTAE as well as BTCS and PVCS were the same. They were produced by 5 human translators who created up to three paraphrases of the original corpus sentences each.

Details of the IWSLT 2008 spoken language corpus are given in Table 3. The first two columns specify the given data set and provide its type. Besides the “text” resources, all data sets consist of the ASR output (lattices, 1/NBEST lists) and manual transcriptions of the respective read-speech or spontaneous-speech recordings of language lang. The number of sentences are given in the “sent” column and the “avg.len” column shows the average number of words per

Table 3: The IWSLT 2008 Spoken Language Corpus

| data set (data type) | lang | sent | avg.len | word token | word type | ref.trans | data track |
|----------------------|------|------|---------|------------|-----------|-----------|------------|
| training (text) C    | 19972| 6.5  | 130,624 | 18,147     | 4,808     |         | BTAE       |
| training (text) E    | 20000| 6.8  | 135,518 | 9,185      |           |         | PVCS, CT_ECE, BTCS, BTCS |
| training (text) E    | 19972| 7.7  | 153,178 | 7,294      |           |         | CT_ECE, CT_ECE, BTCS, BTCS |
| training (text) S    | 19972| 7.4  | 147,560 | 9,021      |           |         | BTAE, PVCS |
| devset1 (read-speech) A | 506  | 5.0  | 2,555   | 1,136      |           |         | BTAE       |
| devset1 (read-speech) C | 506  | 5.5  | 2,808   | 877        |           |         | BTCS       |
| devset1 (text) E     | 8,096| 6.8  | 55,383  | 2,134      | 16        |         | BTCS, BTAE |
| devset2 (read-speech) A | 500  | 5.3  | 2,660   | 1,237      |           |         | BTAE       |
| devset2 (read-speech) C | 500  | 5.8  | 2,906   | 917        |           |         | BTCS       |
| devset2 (text) E     | 8,096| 6.9  | 55,027  | 2,233      | 16        |         | BTCS, BTAE |
| devset3 (read-speech) A | 506  | 5.1  | 2,566   | 1,263      |           |         | BTAE       |
| devset3 (read-speech) C | 506  | 5.8  | 3,209   | 929        |           |         | BTCS, BTCS, PVCS |
| devset3 (text) E     | 8,096| 6.9  | 55,959  | 2,323      | 16        |         | BTCS, BTAE, PVCS |
| devset3 (text) S     | 8,096| 6.3  | 50,420  | 2,616      | 16        |         | BTCS, PVCS |
| devset4 (spontaneous) A | 489  | 8.6  | 4,185   | 1,618      |           |         | BTAE       |
| devset4 (spontaneous) C | 489  | 10.7 | 5,226   | 1,142      |           |         | BTCS       |
| devset4 (text) E     | 3,423| 11.4 | 39,174  | 1,817      | 7         |         | BTCS, BTAE |
| devset5 (spontaneous) A | 500  | 9.3  | 4,652   | 1,950      |           |         | BTAE       |
| devset5 (spontaneous) C | 500  | 11.1 | 5,566   | 1,338      |           |         | BTCS       |
| devset5 (text) E     | 3,500| 12.6 | 44,079  | 2,036      | 7         |         | BTCS, BTAE |
| devset6 (spontaneous) A | 489  | 4.9  | 2,383   | 1,164      |           |         | BTAE       |
| devset6 (spontaneous) C | 489  | 5.4  | 2,647   | 878        |           |         | BTCS       |
| devset6 (text) E     | 2,934| 6.4  | 18,776  | 1,362      | 7         |         | BTCS, BTAE |
| devset7 (spontaneous) C | 1,757| 5.2  | 9,136   | 553        | 7         |         | CT_ECE |
| devset7 (spontaneous) E | 246  | 5.3  | 1,305   | 248        |           |         | CT_ECE |
| devset7 (text) E     | 1,722| 7.0  | 12,076  | 577        | 7         |         | CT_ECE |
| testset (text) C     | 3,486| 5.7  | 20,016  | 708        | 7         |         | CT_ECE |
| testset (spontaneous) A | 504  | 5.0  | 2,513   | 385        |           |         | CT_ECE |
| testset (spontaneous) E | 498  | 5.8  | 2,867   | 312        |           |         | CT_ECE |
| testset (read-speech) A | 507  | 5.1  | 2,858   | 1,205      |           |         | BTAE       |
| testset (read-speech) C | 507  | 5.5  | 2,808   | 885        |           |         | BTCS, BTCS |
| testset (text) E     | 8,112| 6.8  | 55,082  | 2,146      | 16        |         | BTCS, BTAE |
| testset (text) S     | 8,112| 6.2  | 50,169  | 2,569      | 16        |         | BTCS, PVCS |

*An exception was Arabic, with only two native speakers.
Table 4: Out-Of-Vocabulary Rates

| data set | lang | OOV (%) | data track |
|----------|------|---------|-----------|
| devset1  | A    | 5.5     | CT – BT  |
|          | C    | 5.0     | PV – CT  |
|          | E    | 2.3     | CT – BT  |
| devset2  | A    | 5.7     | CT – BT  |
|          | C    | 4.1     | PV – CT  |
|          | E    | 2.5     | CT – BT  |
| devset3  | A    | 3.3     | CT – BT  |
|          | C    | 3.0     | CT – BT  |
|          | E    | 3.4     | CT – BT  |
| devset4  | A    | 16.1    | CT – BT  |
|          | C    | 3.5     | CT – BT  |
|          | E    | 3.8     | CT – BT  |
| devset5  | A    | 17.3    | CT – BT  |
|          | C    | 4.2     | CT – BT  |
|          | E    | 4.7     | CT – BT  |
| devset6  | A    | 18.0    | CT – BT  |
|          | C    | 3.3     | CT – BT  |
|          | E    | 3.0     | CT – BT  |
| testset  | A    | 9.9     | CT – BT  |
|          | C    | 2.9     | CT – BT  |
|          | E    | 3.0     | CT – BT  |

training sentence where the word segmentation for the source language was the one given by the output of the ASR engines without punctuation marks. The English target sentences were tokenized according to the evaluation specifications used for this year’s evaluation campaign. “Word token” refers to the number of words in the corpus and “word type” refers to the vocabulary size. The number of reference translations used for the evaluation of the respective evaluation data sets is given in the “ref.trans” column. In addition, all data tracks that permitted the usage of the respective resources are listed in the “data track” column. All resources of the BTCE resources.

In order to get an idea of how difficult the IWSLT 2008 translation tasks were, we used the SRI Language Modeling Toolkit\(^7\) to train standard 5-gram language models on the target language side of the supplied training corpora and evaluated the entropy and total entropy, i.e., the entropy multiplied by word counts, of each language on the respective evaluation data sets. The entropy figures given in Table 5 indicate that CTCE can be expected to be the easiest task and that the BTEC Task can be expected to be more difficult to translate than the Challenge Task. This is confirmed for the CRR inputs by the automatic evaluation results listed in Appendix C. However, this is not the case for the ASR output translation results which indicates that recognition errors have a larger impact on the Challenge Task translation results compared to the ones of the BTEC Task.

The recognition accuracies of the utilized ASR engines for the IWSLT 2008 evaluation data sets are summarized in Table 6. The lattice accuracy figures show the percentage of correct recognition results contained in the lattices, where the 1BEST accuracy is the accuracy of the best path extracted from each lattice.

Apart from Arabic, the word accuracies of the utilized ASR engines ranged between 87%-95% (lattice) and 79%-86% (1BEST), where the percentages of correctly recognized sentences (sentence accuracy) ranged between 65%-80% (lattice) and 53%-63% (1BEST). The 1BEST recognition results for the Arabic speech data were much lower (word: 73%; sentence: 36%). Unfortunately, the lattice accuracies for Arabic were not available.

Concerning different data types, similar lattice accuracies were obtained for CTCE and BTCE. However, CTCE’s 1BEST recognition results on sentence-level are 10% lower than the BTCE recognition results which seem to cause worse CTCE ASR output translation results than for the BTCE task (see Section 3).

2.2. Evaluation Specifications

The official evaluation specifications for IWSLT 2008 were identical to the ones used in the IWSLT 2006 and 2007 evaluation campaigns and were defined as:

- case-sensitive
- with punctuation marks ( , . ? ! ’ “ )

For the convenience of the participants, automatic evaluation scores were also calculated for the following additional evaluation specifications:

- case-insensitive (lower-case only)
- no punctuation marks (remove , . ? ! ’ “ ”)

The focus of this year’s evaluation campaign was the translation of speech data. Therefore, all input data files were case-insensitive and without punctuation information. However, true-case and punctuation information was provided.

\(^7\)http://www.speech.sri.com/projects/srilm
Table 5: Language Model Perplexity

| data set | lang | entropy | words | total entropy | data track |
|----------|------|---------|-------|---------------|------------|
| devset   | IWSLT08 | C      | 9.71  | 1,710         | 9.71       | CT_EC     |
|          |       | E      | 9.84  | 1,980         | 19,483     | CT_CE     |
| testset  | IWSLT08 | C      | 9.51  | 3,962         | 9.51       | CT_CE     |
|          |       | E      | 10.10 | 3,662         | 36,986     | CT_CE     |
|          |       | S      | 10.25 | 3,885         | 39,821     | BT_CE, BT_AE |

Table 6: Recognition Accuracy

| data set (data type) | lang | word (%) | sentence (%) | data track |
|----------------------|------|----------|--------------|------------|
| devset (spontaneous) | IWSLT08 | C      | 95.33  | 86.90 | 78.46  | 58.54 | CT_CE |
|                      |       | E      | 90.41  | 80.98 | 72.11  | 53.78 | CT_EC |
| testset (spontaneous)| IWSLT08 | C      | 95.07  | 85.79 | 79.56  | 53.77 | CT_CE |
|                      |       | E      | 87.27  | 79.77 | 65.06  | 53.01 | CT_EC |
| testset (read-speech)|       | A      | –      | 72.80 | – 36.10 | – 36.10 | BT_CE, BT_AE |
|                      |       | C      | 94.20  | 83.61 | 80.47  | 63.31 | BT_CE, BT_AE, PV_CS |

Table 7: Automatic Evaluation Metrics

|       | BLEU: the geometric mean of n-gram precision by the system output with respect to reference translations. Scores range between 0 (worst) and 1 (best) [5] |
|-------|----------------------------------------------------------------------------------|
| METEOR: a metric that calculates unigram overlaps between a translation and reference texts taking into account various levels of matches (exact, stem, synonym). Scores range between 0 (worst) and 1 (best) [6] | |

2.2.1. Automatic Evaluation

The automatic evaluation of run submissions was carried out using a large number of standard automatic evaluation metrics whereby the automatic metric scores of all primary and contrastive runs were sent back to the participants one week after the run submission period.

For the official evaluation results\textsuperscript{11} of the IWSLT 2008 workshop, we utilized the average score (“\((B+M)/2\)”) of the two automatic evaluation metrics listed in Table 7.

Table 8: Human Assessment

| Fluency | Adequacy |
|---------|----------|
| 4       | 4        |
| Flawless C/E/S | All Information |
| 3       | 3        |
| Good C/E/S     | Most Information |
| 2       | 2        |
| Non-native C/E/S | Much Information |
| 1       | 1        |
| Disfluent C/E/S | Little Information |
| 0       | 0        |
| Incomprehensible | None |

Due to high evaluation costs, the fluency and adequacy assessments were limited to MT outputs of four systems per data track. The systems were selected based on the obtained “\((B+M)/2\)” automatic evaluation scores as well as the amount of innovative ideas carried out for this year’s event by the participants. Moreover, in order to get an idea of the range of translation quality, MT systems covering the top, middle, and lower performance levels of the respective data track were selected. In total, 24 run submissions were evaluated using the fluency and adequacy criteria. In order to reduce the costs further, the human assessment was limited to the translation outputs of 300 input sentences selected from the

\textsuperscript{10}\url{http://www.slt.atr.jp/IWSLT2008/downloads/case+punc_tool_using_SRILM.instructions.txt}

\textsuperscript{11}In addition to the official evaluation metrics used for IWSLT 2008, the word error rate (WER)\textsuperscript{10}, the position-independent WER (PER)\textsuperscript{11}, the translation error rate (TER)\textsuperscript{12}, and the general text matcher (GTM)\textsuperscript{13} and NIST\textsuperscript{14} scores were also calculated and provided to the participants for the analysis of their systems.

\textsuperscript{12}Fluency grades are defined for the respective target language (C: Chinese, E: English, S: Spanish).
respective testset data sets. In addition, all translation results were pooled, i.e., in case of identical translations of the same source sentence by multiple engines, the translation was graded only once, and the respective rank was assigned to all MT engines with the same output. Each translation was evaluated by at least three judges where each system score is calculated as the median of the assigned grades. The evaluation was carried out by 22 native speakers and 2 non-native speakers with sufficient knowledge of the target language (see Table 9). All graders took part in a dry-run evaluation exercise in order to get used to the evaluation metrics as well as the browser-based graphical user interfaces.

In addition to the fluency/adequacy evaluation, an additional subjective evaluation metric that ranks MT system outputs according to their translation quality was applied to all primary runs submitted by the participants. For the ranking evaluation, human graders were asked to “rank each whole sentence translation from Best to Worst relative to the other choices (ties are allowed)” [7]. Similar to the fluency/adequacy assessments, the ranking evaluation was carried out using a web-browser interface and graders had to order up to five system outputs by assigning a grade between 5 (best) and 1 (worst). The ranking scores were obtained as the average number of times that a system was judged better than any other system. In addition, normalized ranks (NormRank) on a per-judge basis using the method of [15] were calculated for each run submission.

Moreover, a paired-comparison evaluation based on the obtained ranking results was carried out in order to compare two MT systems directly, i.e., given two MT system translations of the evaluation data set, the first system was compared towards the second system output on a sentence-by-sentence basis according to the ranking grades where both systems were ranked together. The gain of the first system towards the second system was defined as the difference between the number of translations ranked better and the number of translations ranked worse divided by the total amount of gradings carried out together. In addition, the difference of each MT system and the system that obtained the highest ranking score (BestRankDiff) was calculated and used to define an alternative method to rank MT systems of a given data track.

2.2.3. Grader Consistency

In order to investigate the degree of grading consistency between the human evaluators, we calculated Fleiss’ kappa coefficient $\kappa$, which measures the agreement between two raters who each classify $N$ items into $C$ mutually exclusive categories taking into account the agreement occurring by chance. It is calculated as:

$$\kappa = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)},$$

where $\Pr(a)$ is the relative observed agreement among graders, and $\Pr(e)$ is the hypothetical probability of chance agreement. If the raters are in complete agreement then $\kappa = 1$. If there is no agreement among the raters (other than what would be expected by chance) then $\kappa \leq 0$. The interpretation of the $\kappa$ values according to [16] is given in Table 10.

2.2.4. Statistical Significance of Evaluation Results

In order to decide whether the translation output on document-level of one MT engine is significantly better than another one, we used the bootStrap method that (1) performs a random sampling with replacement from the evaluation data set, (2) calculates the respective evaluation metric score of each engine for the sampled test sentences and the difference between the two MT system scores, (3) repeats the sampling/scoring step iteratively, and (4) applies the Student’s $t$-test at a significance level of 95% confidence to test whether the score differences are significant [17]. In this year’s evaluation, 2000 iterations were used for the analysis of the IWSLT 2008 automatic evaluation results.

2.2.5. Correlation between Evaluation Metrics

Correlations between different metrics were calculated using the Spearman rank correlation coefficient $\rho$ which is a non-parametric measure of correlation that assesses how well an arbitrary monotonic function could describe the relationship between two variables without making any assumptions about the frequency distribution of the variables. It is calculated as:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)},$$

where $d_i$ is the difference between the rank of the system $i$ and $n$ is the number of systems.

3. Evaluation Results

The evaluation results of the IWSLT 2008 workshop are summarized in Appendix B (human assessment) and Appendix C (automatic evaluation). The correlation rank coefficients of subjective and automatic evaluation results are given in Appendix D. For each evaluation metric, the best score of each data track is marked in boldface.
3.1. Subjective Evaluation Results

Each sentence was evaluated by at least three human judges. Due to different levels of experience and background of the evaluators, variations in judgments were to be expected. Besides the inter-grader consistency, we also calculated the intra-grader consistency using 100 randomly selected evaluation pages that had to be graded a second time. The $\kappa$ coefficients for intra-grader and inter-grader consistencies are given in Table 11 and Table 12. The highest $\kappa$ coefficient for each subjective metric is marked in boldface.

The obtained overall intra-grader $\kappa$ coefficients were high ($\text{fluency: 0.64$, \text{adequacy: 0.70$, \text{ranking: 0.59$)}$ and showed that all graders submitted very consistent evaluation grades. Substantial agreement levels were achieved for most evaluation tasks with Chinese and English as the target language. Only moderate agreement was achieved for the repeated fluency assessments of Spanish translation results. Concerning the evaluation types, the levels of intra-grader consistency were: adequacy > fluency > ranking.

However, the picture is reversed for the inter-grader consistency evaluation. The best level of agreement was achieved for the ranking metrics (overall: 0.50, moderate agreement), followed by adequacy (overall: 0.38) and fluency (overall: 0.35) achieving only a fair agreement between the graders of the respective data tracks. In the case of fluency only a slight agreement could be achieved for Spanish. These low $\kappa$ coefficients for Spanish might be partly caused by (1) the lower translation quality of the Spanish MT outputs and (2) the lower level of experience of the first-time Spanish volunteers compared to the (partly professional) evaluators who had already taken part in the Chinese and English translation tasks of previous IWSLT evaluation campaigns.

The criteria for fluency and adequacy seems to be more precise (→ higher intra-grader consistency), but allow for more variations in grading results due to a larger amount of choices and to different interpretations of the grades by each evaluator (→ lower inter-grader consistency).

In order to minimize the impact of grader inconsistencies, only the grading results of the three most self-consistent graders of each data track were utilized and the median of the assigned grades was selected for the fluency/adequacy assessments as the final judgment for each sentence.

3.1.1. Fluency/Adequacy Performance

The results of the IWSLT 2008 fluency/adequacy evaluation for the primary ASR output runs are summarized in Appendix B.1. For each of the selected MT system outputs, the mean score and the 95% confidence intervals were calculated according to the bootStrap method [17]. The systems are ordered according to the average of the respective mean fluency and adequacy scores with the highest metric scores marked in boldface. The four systems were selected so that they cover the full range of translation quality (high – middle – low) for each data track. Therefore, it was to be expected that all differences in the metric scores were significantly different and that the system with highest average score was also ranked first in the single metrics. However, an exception was the grey system of the PVCS data track which obtained the highest fluency score, but the worst adequacy score.

Moreover, the fluency/adequacy scores differ largely between the data tracks. The highest average scores were obtained for BTCS (fluency: 3.21, adequacy: 2.46), followed by BTCE (fluency: 3.27, adequacy: 2.36), CTCE (fluency: 2.75, adequacy: 2.39), and BTAE (fluency: 3.15, adequacy: 2.18). The lowest translation quality was achieved for the Spanish translation tasks, i.e., BTCS (fluency: 2.50, adequacy: 1.87) and PVCS (fluency: 2.5, adequacy: 1.81).

3.1.2. Ranking Performance

The results of the IWSLT 2008 ranking evaluation are summarized in Appendix B.2. For each data track, all systems are ranked according to the ranking scores, i.e., the average number of times that a system was judged better than any other systems. Although the given rankings slightly differ compared to those rankings based on the NormRank scores for all data tracks besides BTCS, both metrics agree on the top-ranked MT system, which is the tch system for all non-English data tracks (CTCE, BTCS, PVCS), the nlpr system for the Chinese-English tasks (CTCE, BTCE) and the mitll system for BTAE.

In order to get an idea about how different the performances of two given systems are, we performed a paired-comparison for all system combinations and calculated the gain of the first system towards the second system as the difference of the number of translations of the first system ranked better than the ones of the second system and the number of translations ranked worse, divided by the number of times both systems were ranked together. The results listed in Appendix B.3. indicate some inconsistencies of the rankings metric, because several MT system combinations result in negative gains when compared directly.

In order to avoid these inconsistencies, we calculated the BestRankDiff scores that rank all MT systems of each data track according to the percentage of translations the top-scoring system gains to the respective system. The alternative MT system rankings based on the BestRankDiff scores are given in Appendix B.4.

| Metric | CTCE | CTCE | BTA | BTA | PVCS |
|--------|------|------|-----|-----|------|
| fluency | 0.64 | 0.71 | 0.75 | 0.71 | 0.52 |
| adequacy | 0.74 | 0.68 | 0.81 | 0.61 | 0.67 |
| ranking | **0.73** | 0.56 | 0.69 | 0.56 | 0.52 |

| Metric | CTCE | CTCE | BTA | BTA | PVCS |
|--------|------|------|-----|-----|------|
| fluency | 0.41 | 0.38 | 0.41 | **0.44** | 0.19 |
| adequacy | 0.40 | 0.41 | 0.46 | **0.47** | 0.26 |
| ranking | **0.57** | 0.52 | 0.56 | 0.54 | 0.47 |

Table 11: Intra-Grader Consistency

Table 12: Inter-Grader Consistency
3.2. Automatic Evaluation Results

The automatic evaluation results of all MT engines using the official evaluation specifications, i.e., case-sensitive with punctuation marks tokenized, as well as the additional evaluation specifications, i.e., lowercase without punctuation marks, are listed in Appendix C. All primary run submission results for the ASR output translations are given on the lefthandside and the ones for the CRR input conditions are given on the righthandside of the tables. The MT systems are ordered according to the average of the BLEU and METEOR scores obtained for the primary run submission of the ASR output translation condition. If system performances do not differ significantly according to the bootStrap method, horizontal lines between two MT engines in the MT engine ranking tables are omitted. For each data track, the highest scores of the respective evaluation metric are highlighted in boldface.

Besides the CT\textsubscript{CE} task where the two top-ranked systems were not significantly different, the MT systems of all data tracks that obtain the highest automatic evaluation scores agree with the top-ranked systems according to the human assessment results. However, the MT system rankings based on the automatic evaluation scores differ largely from those of the subjective evaluation scores.

3.3. Evaluation Metric Correlations

In order to get an idea of how closely the respective metrics are related, the Spearman rank correlation coefficients were calculated for all automatic evaluation metric combinations. Appendix D summarizes the comparison of the human assessment results and the official automatic evaluation metrics. Due to the limited number of graded systems, the obtained correlation coefficients for fluency and adequacy in Appendix D.1. might not be conclusive, but the results seem to confirm findings of previous IWSLT campaigns that fluency correlates well with BLEU and that adequacy correlates well with METEOR for the given travel tasks. An exception again is the PV\textsubscript{CS} data track, where none of the automatic evaluation metrics agreed with the obtained fluency rankings.

A larger number of systems was used for the calculation of the correlation coefficients for the ranking metrics. The results in Appendix D.2. show that the NormRank metric correlates consistently better with automatic evaluation metrics than the ranking metric. However, the highest correlation coefficients were obtained for the BestRankDiff metric, especially when the systems are ranked according to the official automatic evaluation metrics “(B+M)/2”.

4. Discussion

4.1. Challenge Task 2008

The novelty of this year’s evaluation campaign was the usage of machine-mediated spontaneous speech data collected in field experiments using inexperienced users and state-of-the-art speech-to-speech technologies. In order to identify differences between such real-world data sets towards the more synthetic data collections of the BTEC\textsuperscript{*} corpus, we compared the outcomes of the Challenge Task (CT\textsubscript{CE}) and the BTEC Task using the Chinese-English translation results.

CT\textsubscript{CE} sentences were on average shorter (see Table 3) and less complex (see Table 5) than the BTEC\textsuperscript{*} sentences, but the translation quality of the system outputs for the ASR output condition were worse than those of the BT\textsubscript{CE} translation results. Although quite similar ASR recognition performance was achieved in terms of lattice input (word: 95%, sentence: 80%) and 1BEST word accuracy (84%), the recognition performance for the CT\textsubscript{CE} data sets on sentence-level were much worse, i.e., a large drop of 10% in sentence-level recognition accuracy for 1BEST were obtained (see Table 6). Unfortunately, most participants used only the 1BEST input for both, the CT\textsubscript{CE} and the BT\textsubscript{CE}, translation tasks, thus resulting in lower ASR output scores for CT\textsubscript{CE}.

4.2. Language Dependency

Although it is difficult to compare translation results across different languages and evaluation data sets, the overall translation quality of the primary run submissions of the CT\textsubscript{CE} translation tasks seems to be higher than the results for the Challenge Task of 2006. The reasons are the lower complexity of this year’s Challenge Task. However, the small amount of in-domain language resources might have prevented better translations due to the out-of-vocabulary and domain-mismatch problems of statistical models. Concerning the translation quality of this year’s translations tasks, the data tracks can be ordered according to the fluency and adequacy assessment of the ASR output condition as:

\[ \text{BT}_{\text{CE}} > \text{CT}_{\text{CE}} \approx \text{CT}_{\text{AE}} > \text{BT}_{\text{AE}} > \text{BT}_{\text{CS}} > \text{PV}_{\text{CS}} \]

4.3. Evaluation Metrics

It is well known that human assessments of fluency and adequacy judgments is quite expensive, even if cost reduction methods, like pooling and evaluation data size limitation, are applied. Therefore, not enough systems could be evaluated for fluency and adequacy during this year’s subjective evaluation to make reliable comparisons to automatic evaluation metrics. The ranking metric requires lower evaluation costs, because multiple systems are judged simultaneously. However, the usage of this metric alone is not sufficient because ranking scores can only define a relative order, without providing information on the overall (absolute) translation quality of the respective MT systems. In the extreme case, all MT systems could be good or all MT systems could be bad. Moreover, the ranking metric compares a single system towards more than one other system simultaneously, but the points of reference, i.e., the subset of other systems ranked together, might differ for each system. Therefore, a direct comparison between two MT systems using ranking and NormRank scores might be incorrect, as shown by the negative gains obtained for several systems of the paired-comparison evaluation.
In contrast, the BestRankDiff metric scores are based on those ranking results where two MT systems were ranked together and the same point of reference is used. Thus, a direct relative comparison where the absolute translation quality is defined by the difference in performance with the best scoring system is possible. For IWSLT 2008, the BestRankDiff metric achieved the best correlation towards the official automatic evaluation metrics \( \frac{B+M}{2} \). However, the agreement between the top-scoring MT systems according to the \( \frac{(F+A)}{2} \) and the ranking metrics for all IWSLT 2008 data tracks and the highest inter-grader consistency coefficients showed that the ranking method is a reliable method to identify the best performing system.

In order to minimize evaluation costs, to obtain consistent judgments of overall machine translation quality, and to be able to reliably define a relative ordering on MT systems, future IWSLT evaluations could be carried out as follows: for each data track, (1) a ranking evaluation for all primary system outputs will be performed to identify the best-performing MT system for each track, (2) a fluency/adequacy assessment will be carried out for best MT system only using the full data set and more than three human graders, and (3) systems will be ranked according to the BestRankDiff metric scores.

5. Conclusion

This year’s workshop provided a testbed for verifying the quality of state-of-the-art speech-to-speech translation technologies for real-world applications using machine-mediated spontaneous speech data collected from inexperienced users in a real situation. Various innovative ideas were explored, most notably increase of synthetic training resources by translating in-domain monolingual resources, advanced techniques for phrase extraction from NBEST alignments, improved statistical modeling techniques, system combinations, and rescoring/reranking methods of NBEST lists. Although this year’s evaluation data sets did not take into account the full context of the face-to-face conversations, new insights into the requirements of speech translation technologies for real world applications were obtained that will help to advance the current state-of-the-art in speech-to-speech translation.

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7. References

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### Appendix A. MT System Overview

| Research Group                                                                 | MT System Description                                                                 | Type | System | Submissions       |
|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------|--------|-------------------|
| Carnegie Mellon University, Inter-ACT Research Labs (USA)                    | The CMU Syntax-Augmented Machine Translation System: SAMT on Hadoop with N-best Alignments [18] | SMT  | cmu    | BT<sub>CE</sub>   |
| Dublin City University, School of Computing (Ireland)                        | Exploiting Alignment Techniques in MaTrEx: the DCU Machine Translation System for IWSLT08 [19] | SMT  | dcu    | CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>CE</sub>, BT<sub>AE</sub>, BT<sub>CS</sub>, PV<sub>CS</sub> |
| Fondazione Bruno Kessler, Ricerca Scientifica e Tecnologica (Italy)          | FBK @ IWSLT-2008 [20]                                                               | SMT  | rbk    | CT<sub>EC</sub>, BT<sub>CE</sub>, BT<sub>CS</sub>, PV<sub>CS</sub> |
| University of Caen Basse-Normandie, GREYC (France)                          | The GREYC Machine Translation System for the IWSLT 2008 Evaluation Campaign [21]       | EBMT | greyc  | BT<sub>CE</sub>, BT<sub>AE</sub>, BT<sub>CS</sub>, PV<sub>CS</sub> |
| Institute for Infocomm Research (Singapore)                                 | I^2R Multi-Pass Machine Translation System for IWSLT 2008 [22]                       | SMT  | i2r    | CT<sub>EC</sub>, BT<sub>CE</sub> |
| Chinese Academy of Sciences, Institute of Computing Technology (China)       | The ICT System Description for IWSLT 2008 [23]                                       | SMT  | ict    | CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>CE</sub> |
| University J. Fourier, GETALP, LIG (France)                                 | The LIG Arabic/English Speech Translation System at IWSLT08 [24]                    | SMT  | lig    | BT<sub>AE</sub>   |
| University of Le Mans, LIUM (France)                                        | The LIUM Arabic/English Statistical Machine Translation System for IWSLT 2008 [25]   | SMT  | lium   | BT<sub>AE</sub>   |
| MIT Lincoln Laboratory (USA)                                                 | The MIT-LL/AFRL IWSLT-2008 MT System [26]                                            | SMT  | mitll  | CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>AE</sub> |
| National Institute of Information and Communications Technology (Japan)      | The NICT/ATR Speech Translation System for IWSLT 2008 [27]                           | SMT  | nict   | CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>CE</sub>, BT<sub>CS</sub>, PV<sub>CS</sub> |
| Chinese Academy of Sciences, National Laboratory of Pattern Recognition (China)| The CASIA Statistical Machine Translation System for IWSLT 2008 [28]                  | SMT  | nlpr   | CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>CE</sub> |
| NTT Communication Science Laboratories (Japan)                               | NTT Statistical Machine Translation System for IWSLT 2008 [29]                       | SMT  | ntt    | CT<sub>EC</sub>   |
| Pohang University of Science and Technology (Korea)                          | POSTECH Machine Translation System for IWSLT 2008 Evaluation Campaign [30]            | SMT  | postech| BT<sub>CE</sub>, BT<sub>AE</sub>, BT<sub>CS</sub> |
| Queen Mary University of London (UK)                                         | The QMUL System Description for IWSLT 2008 [31]                                      | SMT  | qmul   | BT<sub>CE</sub>, BT<sub>AE</sub>, PV<sub>CS</sub> |
| Rheinisch Westfälische Technische Hochschule (Germany)                      | The RWTH Machine Translation System for IWSLT 2008 [32]                               | SMT  | rwth   | CT<sub>EC</sub>, BT<sub>CE</sub>, BT<sub>AE</sub> |
| UPC, TALP Research Center (Spain)                                           | The TALP & I2R SMT Systems for IWSLT 2008 [33]                                       | SMT  | talp   | BT<sub>AE</sub>, BT<sub>CS</sub>, PV<sub>CS</sub> |
| Toshiba China R&D Center (China)                                             | The TCH Machine Translation System for IWSLT 2008 [34]                                | SMT  | tch    | CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>CE</sub>, BT<sub>CS</sub>, PV<sub>CS</sub> |
| Tottori University (Japan)                                                   | Statistical Machine Translation without Long Parallel Sentences for Training Data [35] | SMT  | tottori| CT<sub>EC</sub>, CT<sub>CE</sub>, BT<sub>CE</sub> |
| TÜBİTAK-UEKAE (Turkey)                                                       | The TÜBİTAK-UEKAE Statistical Machine Translation System for IWSLT 2008 [36]          | SMT  | tubitak| BT<sub>CE</sub>, BT<sub>AE</sub>, BT<sub>CS</sub>, PV<sub>CS</sub> |
## Appendix B. Human Assessment

### B.1. Fluency/Adequacy

- The mean score and the 95% confidence intervals were calculated for each MT output according to the bootStrap method [17].
- The MT systems are ordered according to the average of mean fluency and adequacy scores.

| MT           | Fluency | Adequacy  |
|--------------|---------|-----------|
| tch.ASR.1    | 2.3894  | [2.2071, 2.5716] |
| icl.ASR.1    | 2.2442  | [2.0600, 2.4284] |
| nlpr.ASR.5   | 2.2784  | [2.1006, 2.4563] |
| tomtori.ASR.1| 1.6592  | [1.4804, 1.8379] |

### B.2. Ranking

- The Ranking scores are the average numbers of times that a system was judged better than any other system.
- The NormRank scores are normalized ranks on a per-judge basis using the method of [15].

| MT           | NormRank | Ranking |
|--------------|----------|---------|
| tch.ASR.1    | 0.3966   | 2.38    |
| nlpr.ASR.5   | 0.3806   | 2.24    |
| icl.ASR.1    | 0.3752   | 2.28    |
| nict.ASR.1   | 0.3043   | 2.10    |
| nict.ASR.20  | 0.2095   | 1.71    |
| miltl.ASR.SLF| 0.1952   | 1.69    |
| tomtori.ASR.1| 0.1838  | 1.61    |

| MT           | NormRank | Ranking |
|--------------|----------|---------|
| tch.ASR.1    | 0.4773   | 2.45    |
| icl.ASR.1    | 0.3342   | 2.11    |
| nict.ASR.1   | 0.2899   | 2.00    |
| dcu.ASR.1    | 0.2832   | 2.00    |
| talp.ASR.1   | 0.2642   | 1.95    |
| postech.ASR.1| 0.2332  | 1.83    |

| MT           | NormRank | Ranking |
|--------------|----------|---------|
| tch.ASR.1    | 0.4932   | 2.47    |
| icl.ASR.1    | 0.3990   | 2.27    |
| nict.ASR.1   | 0.3545   | 2.10    |
| nict.ASR.20  | 0.3416   | 2.12    |
| dcu.ASR.1    | 0.3172   | 2.03    |
| nict.ASR.1   | 0.3088   | 2.01    |
| nict.ASR.20  | 0.1772   | 1.56    |
| tomtori.ASR.1| 0.1546   | 1.44    |

## Appendix C. MT System Comparison

| System       | Fluency | Adequacy  |
|--------------|---------|-----------|
| miltl.ASR.SLF| 2.1813  | [1.9797, 2.3648] |
| talp.ASR.1   | 1.9968  | [1.8208, 2.1727] |
| dcu.ASR.1    | 1.9877  | [1.8165, 2.1588] |
| qmul.ASR.1   | 1.4510  | [1.2879, 1.6141] |

| System       | Fluency | Adequacy  |
|--------------|---------|-----------|
| miltl.ASR.SLF| 0.4415  | 2.42    |
| talp.ASR.1   | 0.3901  | 2.27    |
| r2r.ASR.1    | 0.3822  | 2.21    |
| lig.ASR.1    | 0.3756  | 2.09    |
| lnum.ASR.1   | 0.3741  | 2.19    |
| dcu.ASR.1    | 0.3634  | 2.18    |
| r2r.ASR.1    | 0.3574  | 2.20    |
| qmul.ASR.1   | 0.2289  | 1.64    |
| postech.ASR.1| 0.1977  | 1.59    |
| tomtori.ASR.1| 0.1498  | 1.21    |
B.3. Pairwise Comparison

(best = 1.0, ..., worst = -1.0)

- the outputs of the first system are compared against the second system on a sentence-by-sentence basis according to the ranking grades.
- the given scores are the ratio of improved translations, i.e. gain = \frac{\text{better translations} - \text{worse translations}}{\text{total translations}}
- the systems are ordered according to the ranking scores of Appendix B.2.

### CTCE

| 1 \text{st} | 2\text{nd} | tch | npr | ic | nict | miltl | tottori |
|-------------|-----------|-----|-----|----|------|-------|--------|
| tch         | 0.0632    | 0.1639 | 0.2892 | 0.3587 | 0.3630 | 0.3547 | 0.4053 | 0.4084 | 0.6436 |
| npr         | -0.0088   | 0.0794 | 0.2915 | 0.2781 | 0.2911 |        |        |        |        |
| ic          | 0.1024    | 0.2809 | 0.3064 | 0.3587 |        |        |        |        |        |
| nict        |          | 0.0317 | 0.0417 |        |        |        |        |        |        |
| miltl       |          |       |        |        |        |        |        |        |        |
| tottori     |          |       |        |        |        |        |        |        |        |

### CTCE

| 1 \text{st} | 2\text{nd} | tch | npr | ic | nict | miltl | tottori |
|-------------|-----------|-----|-----|----|------|-------|--------|
| tch         | 0.0878    | 0.1639 | 0.2892 | 0.3587 | 0.3630 | 0.3547 | 0.4053 | 0.4084 | 0.6436 |
| npr         | -0.0349   | 0.1526 | 0.2022 | 0.2932 | 0.3030 | 0.3780 | 0.2799 | 0.3636 | 0.3500 |
| ic          | 0.0032    | 0.0036 | 0.0848 | 0.0804 | 0.1140 | 0.1847 | 0.2935 | 0.4560 |        |
| nict        | -0.0055   | 0.0676 | 0.1362 | 0.1117 | 0.1024 | 0.1712 | 0.2067 | 0.2911 |        |
| miltl       |          |       |        |        |        |        |        |        |        |
| tottori     |          |       |        |        |        |        |        |        |        |

### BTCE

| 1 \text{st} | 2\text{nd} | tch | ic | nict | miltl | nt | nict | fbk | tottori |
|-------------|-----------|-----|----|------|-------|----|------|-----|--------|
| tch         | 0.0310    | 0.1639 | 0.2892 | 0.3587 | 0.3630 | 0.3547 | 0.4053 | 0.4084 | 0.6436 |
| npr         | -0.0352   | 0.1526 | 0.2022 | 0.2932 | 0.3030 | 0.3780 | 0.2799 | 0.3636 | 0.3500 |
| ic          | 0.0032    | 0.0036 | 0.0848 | 0.0804 | 0.1140 | 0.1847 | 0.2935 | 0.4560 |        |
| nict        | -0.0055   | 0.0676 | 0.1362 | 0.1117 | 0.1024 | 0.1712 | 0.2067 | 0.2911 |        |
| miltl       |          |       |        |        |        |        |        |        |        |
| tottori     |          |       |        |        |        |        |        |        |        |

### BTAE

| 1 \text{st} | 2\text{nd} | talp | rth | cmu | dcu | nict | fbk | nbtkat | miltl | postech | greyc | qmul |
|-------------|-----------|------|-----|-----|-----|------|-----|--------|-------|--------|------|------|
| tch         | 0.0451    | 0.1273 | 0.2203 | 0.0855 | 0.1843 | 0.1222 | 0.0866 | 0.3723 | 0.3728 |        |      |
| npr         | -0.0357   | 0.2148 | 0.1111 | 0.2056 | 0.4034 | 0.3977 | 0.3609 | 0.4779 | 0.3562 | 0.5979 | 0.6614 |
| ic          | -0.0351   | 0.0977 | 0.1725 | 0.2538 | 0.2869 | 0.5623 | 0.2941 | 0.4846 | 0.4740 | 0.5789 | 0.5830 |
| nict        | 0.0894    | 0.1623 | 0.2263 | 0.2842 | 0.2030 | 0.5090 | 0.4160 | 0.5625 | 0.5520 |        |      |
| miltl       |          |       |        |        |        |        |        |        |        |        |      |
| tottori     |          |       |        |        |        |        |        |        |        |        |      |

### BTCS

| 1 \text{st} | 2\text{nd} | fbk | nict | nbtkat | dcu | postech | greyc |
|-------------|-----------|-----|------|--------|-----|---------|------|
| tch         | 0.2649    | 0.2712 | 0.3035 | 0.3658 | 0.3584 | 0.3727 | 0.3639 |
| npr         | 0.0577    | 0.0666 | 0.0479 | 0.1047 | 0.2537 | 0.3049 |        |
| ic          |          | 0.0140 | 0.0680 | 0.0365 | 0.1371 | 0.2449 |        |
| nict        |          | 0.0023 | 0.0333 | 0.1136 | 0.2804 |        |        |
| miltl       |          |       |        |        |        |        |        |
| tottori     |          |       |        |        |        |        |        |
| postech     |          |       |        |        |        |        |        |

### PVCS

| 1 \text{st} | 2\text{nd} | fbk | tch | nict | dcu | qmul | greyc |
|-------------|-----------|-----|-----|------|-----|------|------|
| tch         | 0.1638    | 0.2347 | 0.1902 | 0.2982 | 0.2885 | 0.5042 | 0.5892 |
| npr         | 0.1322    | 0.0848 | 0.1882 | 0.1856 | 0.3727 | 0.4337 |        |
| ic          | 0.0017    | 0.0011 | 0.0880 | 0.3530 | 0.3889 |        |        |
| nict        | 0.0985    | 0.0564 | 0.2950 | 0.3864 |        |        |        |
| miltl       |          |       |        |        |        |        |        |
| tottori     |          |       |        |        |        |        |        |
| postech     |          |       |        |        |        |        |        |

### Greyc

| 1 \text{st} | 2\text{nd} | fbk | nict | miltl | postech | greyc |
|-------------|-----------|-----|------|-------|---------|------|
| tch         | 0.2649    | 0.2712 | 0.3035 | 0.3658 | 0.3584 | 0.3727 | 0.3639 |
| npr         | 0.0577    | 0.0666 | 0.0479 | 0.1047 | 0.2537 | 0.3049 |        |
| ic          |          | 0.0140 | 0.0680 | 0.0365 | 0.1371 | 0.2449 |        |
| nict        |          | 0.0023 | 0.0333 | 0.1136 | 0.2804 |        |        |
| miltl       |          |       |        |        |        |        |        |
| tottori     |          |       |        |        |        |        |        |
| postech     |          |       |        |        |        |        |        |

- 13 -
B.4. Difference To System With Best Ranking Score

The BestRankDiff scores are the ratio of translations that the system with the highest Ranking score ($MT^{top}$) gains to the respective system, i.e. $BestRankDiff = \frac{|translations \text{ ranked worse than } MT^{top}|}{|translations \text{ ranked better than } MT^{top}|}$.

| System  | CT_EC |  |  |  |  |
|---------|-------|-------|-------|-------|-------|
| nlpr.ASR.5 | 0.0632 | 0.2493 | 0.4380 | 0.3125 |
| ic.t.ASR.1 | 0.0665 | 0.2405 | 0.4525 | 0.3070 |
| dcu.ASR.1 | 0.1888 | 0.1774 | 0.4564 | 0.3662 |
| nict.ASR.20 | 0.3147 | 0.1413 | 0.4027 | 0.4560 |
| mitll.ASR.SLF | 0.3231 | 0.1307 | 0.4155 | 0.4538 |
| tottori.ASR.1 | 0.3555 | 0.1270 | 0.3905 | 0.4825 |

| System  | CT_CE |  |  |  |  |
|---------|-------|-------|-------|-------|-------|
| nlpr.ASR.5 | 0.0906 | 0.2875 | 0.3344 | 0.3781 |
| ic.t.ASR.1 | 0.1639 | 0.2459 | 0.3443 | 0.4098 |
| i2r.ASR.1 | 0.2086 | 0.2466 | 0.2982 | 0.4552 |
| mitll.ASR.SLF | 0.2915 | 0.2177 | 0.2731 | 0.5092 |
| ntt.ASR.1 | 0.3548 | 0.2262 | 0.1928 | 0.5810 |
| rwth.ASR.1 | 0.3587 | 0.1702 | 0.2889 | 0.5549 |
| dcu.ASR.1 | 0.3630 | 0.1782 | 0.2806 | 0.5412 |
| nict.ASR.1 | 0.4083 | 0.1704 | 0.2509 | 0.5787 |
| fbk.ASR.1 | 0.4083 | 0.1704 | 0.2509 | 0.5787 |

| System  | BT_AE |  |  |  |  |
|---------|-------|-------|-------|-------|-------|
| talp.ASR.1 | 0.0450 | 0.2575 | 0.4400 | 0.3025 |
| lium.ASR.1 | 0.0855 | 0.2660 | 0.3825 | 0.3515 |
| tubitak.ASR.1 | 0.1222 | 0.2219 | 0.4340 | 0.3441 |
| rwth.ASR.1 | 0.1273 | 0.2090 | 0.4547 | 0.3363 |
| dcu.ASR.1 | 0.1843 | 0.2260 | 0.3637 | 0.4103 |
| lig.ASR.SLF | 0.2200 | 0.2244 | 0.3312 | 0.4444 |
| postech.ASR.1 | 0.3838 | 0.1534 | 0.3094 | 0.5372 |
| qmul.ASR.1 | 0.3958 | 0.1595 | 0.2852 | 0.5553 |
| greyc.ASR.1 | 0.5739 | 0.1034 | 0.2193 | 0.6773 |

| System  | BT_CE |  |  |  |  |
|---------|-------|-------|-------|-------|-------|
| talp.ASR.1 | 0.0528 | 0.2781 | 0.3910 | 0.3309 |
| lium.ASR.1 | 0.0912 | 0.2631 | 0.3826 | 0.3543 |
| cmu.ASR.1 | 0.1292 | 0.2517 | 0.3674 | 0.3809 |
| i2r.ASR.1 | 0.1304 | 0.2282 | 0.4132 | 0.3586 |
| rwth.ASR.1 | 0.1910 | 0.2247 | 0.3596 | 0.4157 |
| fbk.ASR.1 | 0.3660 | 0.1547 | 0.3246 | 0.5207 |
| dcu.ASR.1 | 0.4014 | 0.1131 | 0.3724 | 0.5145 |
| nict.ASR.1 | 0.4276 | 0.1448 | 0.2828 | 0.5724 |
| tubitak.ASR.1 | 0.4312 | 0.1557 | 0.2574 | 0.5869 |
| tomtor.ASR.1 | 0.5154 | 0.1153 | 0.2540 | 0.6307 |
| postech.ASR.1 | 0.5610 | 0.0975 | 0.2440 | 0.6585 |
| greyc.ASR.1 | 0.5993 | 0.1198 | 0.1611 | 0.7191 |
| qmul.ASR.1 | 0.7436 | 0.0512 | 0.1540 | 0.7948 |

| System  | BT_CS |  |  |  |  |
|---------|-------|-------|-------|-------|-------|
| fbk.ASR.1 | 0.2649 | 0.1797 | 0.3757 | 0.4446 |
| nict.ASR.1 | 0.2712 | 0.1373 | 0.4542 | 0.4085 |
| tubitak.ASR.1 | 0.3053 | 0.1378 | 0.4191 | 0.4331 |
| talp.ASR.1 | 0.3584 | 0.1394 | 0.3628 | 0.4978 |
| greyc.ASR.1 | 0.3638 | 0.1610 | 0.3142 | 0.5248 |
| dcu.ASR.1 | 0.3658 | 0.1305 | 0.3732 | 0.4963 |
| postech.ASR.1 | 0.3727 | 0.1501 | 0.3271 | 0.5228 |

| System  | PV_CS |  |  |  |  |
|---------|-------|-------|-------|-------|-------|
| fbk.ASR.1 | 0.1638 | 0.2267 | 0.3828 | 0.3905 |
| nict.ASR.1 | 0.1901 | 0.2140 | 0.3819 | 0.4041 |
| talp.ASR.1 | 0.2346 | 0.2048 | 0.3558 | 0.4394 |
| nict.ASR.1 | 0.2885 | 0.2000 | 0.3115 | 0.4885 |
| dcu.ASR.1 | 0.2987 | 0.1817 | 0.3379 | 0.4804 |
| qmul.ASR.1 | 0.5042 | 0.0892 | 0.3174 | 0.5934 |
| greyc.ASR.1 | 0.5892 | 0.0728 | 0.2652 | 0.6620 |
Appendix C. Automatic Evaluation

- the systems were ranked according to the average score of the BLEU and METEOR metric results of the primary runs for the ASR Output data track.
- omitted lines between scores indicate non-significant differences in performance between the respective MT engines according to the bootStrap method [17].
- the best score of each metric is marked with boldface.

### ASR Output

| (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
|---------|------|--------|---------|------|--------|
| official evaluation | 0.5091 | 0.5545 |
| additional evaluation | 0.3712 | 0.4973 |

| (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
|---------|------|--------|---------|------|--------|
| official evaluation | 0.5667 | 0.6476 |
| additional evaluation | 0.4240 | 0.5233 |

### Correct Recognition Result

| (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
|---------|------|--------|---------|------|--------|
| official evaluation | 0.5814 | 0.6947 |
| additional evaluation | 0.5919 | 0.8159 |

| (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
|---------|------|--------|---------|------|--------|
| official evaluation | 0.5000 | 0.7747 |
| additional evaluation | 0.7597 | 0.6140 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.6082 | 0.7569 |
| additional evaluation | 0.4795 | 0.5703 |

### Correct Recognition Result (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.7039 | 0.8159 |
| additional evaluation | 0.5919 | 0.6947 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.6476 | 0.7882 |
| additional evaluation | 0.5070 | 0.7747 |

### Table

| ASR Output | Correct Recognition Result |
|------------|-----------------------------|
| (B+M)/2    | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
| official evaluation | 0.5667 | 0.6476 |
| additional evaluation | 0.4240 | 0.5233 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5822 | 0.6590 |
| additional evaluation | 0.5189 | 0.6295 |

### Correct Recognition Result (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5900 | 0.5381 |
| additional evaluation | 0.5398 | 0.5010 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5627 | 0.6420 |
| additional evaluation | 0.5627 | 0.6420 |

### Table

| ASR Output | Correct Recognition Result |
|------------|-----------------------------|
| (B+M)/2    | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
| official evaluation | 0.5091 | 0.5545 |
| additional evaluation | 0.3712 | 0.4973 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5667 | 0.6476 |
| additional evaluation | 0.4240 | 0.5233 |

### Correct Recognition Result (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5814 | 0.6947 |
| additional evaluation | 0.5919 | 0.8159 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5000 | 0.7747 |
| additional evaluation | 0.7597 | 0.6140 |

### Table

| ASR Output | Correct Recognition Result |
|------------|-----------------------------|
| (B+M)/2    | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
| official evaluation | 0.5091 | 0.5545 |
| additional evaluation | 0.3712 | 0.4973 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5667 | 0.6476 |
| additional evaluation | 0.4240 | 0.5233 |

### Correct Recognition Result (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5814 | 0.6947 |
| additional evaluation | 0.5919 | 0.8159 |

### Additional Evaluation (B+M)/2

| (B+M)/2 | BLEU | METEOR |
|---------|------|--------|
| official evaluation | 0.5000 | 0.7747 |
| additional evaluation | 0.7597 | 0.6140 |
### Official Evaluation vs. Additional Evaluation

| ASR Output | official evaluation | additional evaluation | BT\_AE | official evaluation | additional evaluation | Correct Recognition Result |
|------------|---------------------|-----------------------|--------|---------------------|-----------------------|---------------------------|
|            | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
| mitil      | 0.4292 | 0.5534 | 0.5784 | 0.5217 | 0.6350 |        |         |         |        |         |         |        |        |
| rwth       | 0.4020 | 0.5293 | 0.5343 | 0.4642 | 0.6043 |        |         |         |        |         |         |        |        |
| lium       | 0.3952 | 0.5342 | 0.5041 | 0.3982 | 0.6100 |        |         |         |        |         |         |        |        |
| talp       | 0.3915 | 0.5267 | 0.5280 | 0.4505 | 0.6054 |        |         |         |        |         |         |        |        |
| mitll      | 0.3904 | 0.5289 | 0.5115 | 0.4189 | 0.6040 |        |         |         |        |         |         |        |        |
| lig        | 0.3881 | 0.5216 | 0.5020 | 0.4080 | 0.5959 |        |         |         |        |         |         |        |        |
| mitll      | 0.3798 | 0.5192 | 0.4993 | 0.4049 | 0.5937 |        |         |         |        |         |         |        |        |
| postech    | 0.3360 | 0.4785 | 0.4312 | 0.3152 | 0.5472 |        |         |         |        |         |         |        |        |
| lium       | 0.3126 | 0.4639 | 0.4151 | 0.3001 | 0.5300 |        |         |         |        |         |         |        |        |
| talp       | 0.2467 | 0.3568 | 0.3197 | 0.2304 | 0.4090 |        |         |         |        |         |         |        |        |

| ASR Output | official evaluation | additional evaluation | BT\_CS | official evaluation | additional evaluation | Correct Recognition Result |
|------------|---------------------|-----------------------|--------|---------------------|-----------------------|---------------------------|
|            | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
| tch        | 0.3109 | 0.3165 | 0.2780 | 0.2699 | 0.2860 |        |         |         |        |         |         |        |        |
| fbk        | 0.2619 | 0.2813 | 0.2461 | 0.2256 | 0.2666 |        |         |         |        |         |         |        |        |
| tubitak    | 0.2594 | 0.2747 | 0.2459 | 0.2332 | 0.2585 |        |         |         |        |         |         |        |        |
| dcu        | 0.2521 | 0.2653 | 0.2303 | 0.2190 | 0.2416 |        |         |         |        |         |         |        |        |
| nict       | 0.2500 | 0.2669 | 0.2397 | 0.2283 | 0.2511 |        |         |         |        |         |         |        |        |
| postech    | 0.2359 | 0.2504 | 0.2209 | 0.2102 | 0.2316 |        |         |         |        |         |         |        |        |
| greyc      | 0.2223 | 0.2436 | 0.2142 | 0.1823 | 0.2460 |        |         |         |        |         |         |        |        |
| greyc      | 0.2021 | 0.2150 | 0.2097 | 0.2039 | 0.2155 |        |         |         |        |         |         |        |        |

| ASR Output | official evaluation | additional evaluation | PV\_CS | official evaluation | additional evaluation | Correct Recognition Result |
|------------|---------------------|-----------------------|--------|---------------------|-----------------------|---------------------------|
|            | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR | (B+M)/2 | BLEU | METEOR |
| tch        | 0.3452 | 0.3360 | 0.3253 | 0.3448 | 0.3057 |        |         |         |        |         |         |        |        |
| fbk        | 0.3212 | 0.3172 | 0.2992 | 0.3079 | 0.2904 |        |         |         |        |         |         |        |        |
| talp       | 0.3144 | 0.2875 | 0.2853 | 0.3088 | 0.2618 |        |         |         |        |         |         |        |        |
| nict       | 0.3103 | 0.2925 | 0.3005 | 0.3275 | 0.2735 |        |         |         |        |         |         |        |        |
| greyc      | 0.2863 | 0.2910 | 0.2578 | 0.2581 | 0.2574 |        |         |         |        |         |         |        |        |
| greyc      | 0.2844 | 0.2680 | 0.2685 | 0.2659 | 0.2710 |        |         |         |        |         |         |        |        |
| qmul       | 0.1755 | 0.2004 | 0.1799 | 0.1604 | 0.1993 |        |         |         |        |         |         |        |        |
| qmul       | 0.1469 | 0.1778 | 0.1666 | 0.1423 | 0.1909 |        |         |         |        |         |         |        |        |
Appendix D. Correlation between Evaluation Metrics

- the correlation between evaluation metrics are measured using the **Spearman’s rank correlation coefficient** $\rho \in [-1.0, 1.0]$ with $\rho = 1.0$ if all systems ranked in same order, $\rho = -1.0$ if all systems ranked in reverse order and $\rho = 0.0$ if no correlation exists
- the number in parentheses behind each data track label indicates the number of ranked MT systems
- the automatic evaluation metrics that correlate best with the respective human assessments are marked in boldface

### D.1. Fluency/Adequacy vs. Automatic Evaluation

| Data Track | Fluency | Adequacy |
|------------|---------|----------|
| **CT** (4) | 1.0000  | 0.8000   |
|            | 1.0000  | 1.0000   |
|            | 0.8000  | 1.0000   |
| **BT** (4) | 0.8000  | 0.8000   |
|            | 0.8000  | 1.0000   |
|            | 1.0000  | 1.0000   |
| **PV** (4) | 0.8000  | 0.8000   |
|            | 0.0000  | 0.0000   |
|            | 1.0000  | 1.0000   |

### D.2. Ranking vs. Automatic Evaluation

| Data Track | Ranking | NormRank | BestRankDiff |
|------------|---------|----------|--------------|
| **CT** (7) | 0.1071  | 0.4286   | 0.4286       |
|            | 0.1071  | 0.4286   | 0.4286       |
|            | 0.1071  | 0.1071   | 0.4286       |
| **BT** (8) | 0.1190  | -0.1667  | 0.6190       |
|            | 0.1190  | -0.1667  | 0.6190       |
|            | -0.1667 | -0.4524  | -0.0238      |
| **PV** (8) | 0.0238  | 0.0476   | 0.4524       |
|            | 0.1190  | 0.1429   | 0.2619       |
|            | 0.6190  | -0.3571  | 0.6190       |