

**SEVENTH FRAMEWORK PROGRAMME**  
**THEME 3**  
**Information and Communication Technologies**

# **PANACEA Project**

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**Platform for Automatic, Normalized Annotation and  
Cost-Effective Acquisition**  
of Language Resources for Human Language Technologies

## **D8.3: Task-based Evaluation of the PANACEA Production Chain**

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### **Relevant PANACEA Deliverables**

<b>D3.4</b>	Third version of the Platform
<b>D4.1</b>	Technologies and tools for corpus creation, normalization and annotation
<b>D4.5</b>	Final prototype of the Corpus Acquisition and Annotation Subsystem
<b>D5.2</b>	Aligners Integrated into the Platform
<b>D5.4</b>	Bilingual Dictionary Extractor
<b>D7.4</b>	Third Evaluation Report
<b>D8.2</b>	Tool-based Evaluation of the PANACEA Production Chain

### *D8.3 Task-based Evaluation of the PANACEA Production Chain*

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## 1 Purpose and Objectives

The work package 8 of PANACEA deals with ‘Industrial Evaluation’; after three development cycles, the final task is to relate the PANACEA developments to real world scenarios. The package has two tasks:

- Tool-based evaluation looks at the main tools, and evaluates their usability in industrial contexts; this is subject of the deliverable D8.2;
- Task-based evaluation uses PANACEA tools to perform a given task, and compares the outcome with conventional procedures. This is subject of the current deliverable (D8.3).

The task was defined in D8-1 to be a multilingual one, in the area of machine translation: adaptation of an MT system to a new domain; this is a frequent task. The domain that has been selected was automotive, and the language direction was German to English. The system of comparison is Linguatrec’s ‘*Personal Translator 14*’.

The question to be answered is if the use of PANACEA tools would improve the domain adaptation task, either by producing superior quality, or by being more efficient than existing adaptation methods.

### 1.1.1 Terminology

The following systems will be described in the following report:

MOSES	baseline SMT system, trained with Europarl. Same as DCUv0
PT	baseline RBMT system: ‘Linguatrec’s ‘ <i>Personal Translator 14</i> ’.
KFZ	adapted RBMT system, using ‘Automotive Dictionary’ for domain adaptation, loading it into the PT baseline
UNK	adapted RBMT system, using unknowns extracted from text and importing it into the PT baseline
DCU	SMT system, with additional in-domain training and development data: same as DCUv1 if not mentioned otherwise.
DCUv0	baseline SMT system: (same as MOSES)
DCUv1	adapted SMT system, with in-domain data in addition to the baseline data
DCUv2	Adapted SMT system, using in-domain data only.
GLO	adapted RBMT system, using a glossary created from DCUv1 system’s phrase tables. Same as GLO2 if not mentioned otherwise
GLO1	a GLO system where all entries were imported (35,100) and overwrite the existing entries
GLO2	a GLO system where only unknown entries were imported (12,900)

## 2 Evaluation Design

### 2.1 Evaluation Scenario

For evaluation, a multilingual / machine translation task was selected, to cover as many PANACEA tools as possible. The task was to adapt a baseline system to a new domain. The domain chosen was automotive, the language direction was German to English.

The scenario consists in creating a baseline system, in this case a commercial out-of-the-box system was used (Linguec's '*Personal Translator 14*', the most-installed system in the German market (Aleksić & Thurmair 2011).

This baseline system should be adapted to the automotive domain, on the one hand by using conventional technology, on the other hand by using PANACEA tools. This is shown in fig. 2-1.

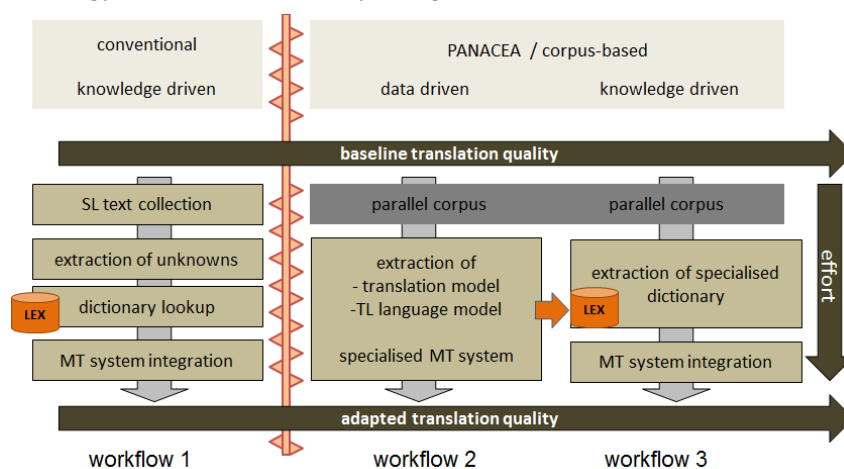


Fig. 2-1: Evaluation scenario

The adapted systems should be compared in quality, and the achieved quality should be compared to the effort needed to achieve it.

### 2.2 Evaluation Methodology

The methodology would consist in the following procedure:

1. Create a baseline system. For rule-based MT, the system is the above-mentioned '*Personal Translator*' (henceforth called 'PT'); for statistical MT, a Moses system trained with Europarl data was created (henceforth called 'MOSES').

2. Create an adapted system. Several systems were produced for the evaluation task:

Conventional adaptation (workflow 1 in fig. 2-1). Two such systems were built:

- a system which includes an existing automotive dictionary, the '*Automotive Dictionary*' ('*KFZ-Lexikon*') offered by Linguatec. The resulting system is referred to as 'KFZ' henceforth.
- a system which takes several automotive files, runs the function 'find unknown terms' which the system offers, and codes the list of unknown terms, using the MT system's coding tool. The resulting system is called 'UNK' in the following.

PANACEA adaptation:

- an SMT translation system which is tuned towards the automotive domain by collecting domain-specific parallel sentences, crawled from automotive web sites, using PANACEA tools: focused

bilingual crawling, sentence splitting, sentence alignment, SMT training (GIZA++, Moses). This system was built by DCU; it is called ‘DCU’ henceforth (cf. workflow 2 in fig. 2-1).

- a system which extracts a glossary from the DCU system’s phrase tables, using the PANACEA P2G tool. The glossary is imported into the MT system as additional dictionary. This system is called ‘GLO’ henceforth (cf. workflow 3 in fig. 2-1).

For all adaptation steps, the effort is recorded, in terms of person hours.

3. Compare the translation quality of the adapted system with the one of the baseline system. This operation results in six comparisons:

PT	vs.	KFZ	
PT	vs.	UNK	(both conventional)
Moses	vs.	DCU	(both SMT systems)
PT	vs.	GLO	(both RMT systems)

In addition, to evaluate the effort for GLO vis-à-vis the DCU, a comparison was made for:

PT	vs.	MOSES	(baseline quality comparison)
GLO	vs.	DCU	(both adapted systems)

4. Finally, relate the quality improvement to the effort needed for adaptation.

## 2.3 Evaluation Data

Two types of evaluation data were used:

- For **efforts**, person hours were counted. As many of the tools (crawling, MOSES) take significant computation effort, the effort was not measured in machine time but in the time where people were involved. Machine time is usually much higher.
- For **quality**, human evaluation was used in addition to automatic scores (BLEU, using one reference translation). As only *comparative* (COMP) evaluation was done, the test persons had to decide which one of two translation outputs was better, if any. Quality change was calculated by: number improvements minus number deteriorations, divided by total amount sentences. This is a standard measure used in industrial MT comparisons. For evaluation, the Sisyphe-II tools made by Linguatrec were used. Two evaluators were engaged to do the evaluations.

For the quality comparison, a test set of 1500 sentences from the automotive domain was used. The test set was taken from crawled automotive texts, so it contains spelling errors, wrong segmentation etc.; no cleaning was done. None of those 1500 sentences is in the training corpus. This test set was used for KFZ and UNK.

For DCU system adaptation, 500 sentences out of the test set were used as development set, so the test set was reduced to 1000 sentences. This reduced test set was used for DCU and GLO.

### 3 System Adaptation

The second step of the evaluation task was to create adapted systems, and measure the time effort needed for the adaptation.

#### 3.1 Non-Panacea Systems

##### 3.1.1 KFZ system

The KFZ system was easily created because there is an Automotive Dictionary already available in the market<sup>1</sup>. It even is already prepared for import into the ‘*Personal Translator*’. This dictionary contains about 36.000 entries in the automotive domain.

The ‘*Personal Translator*’ separates the dictionary into different modules which can be loaded and unloaded at runtime. In translation, these modules are searched sequentially; priority is given to user dictionaries, followed by additional dictionaries, followed by the system dictionary.

Adaptation of the KFZ system simply consists in loading the Automotive Dictionary as additional dictionary.

The effort to produce the KFZ system therefore is 0 person hours. The effort to produce the Automotive Dictionary is unknown but massive.

##### 3.1.2 UNK system

The second option to adapt an MT system in a conventional way is to run an ‘unknown words’ search over a corpus of the domain, and code the unknown terms; this is shown in the workflow 1 in fig. 2-1.

The standard workflow in rule-based MT is to

- run an unknown word search on the text to be translated,
- find translations for those terms,
- import and annotate the unknown terms, using the system’s coding tool,
- and translate the text with an adapted dictionary in the second run.

This workflow must be adapted if a new *domain* is to be prepared, as *multiple* texts can be forwarded: So a corpus of different texts must be collected, which hopefully covers the main terms of the domain.

##### Step 1: Corpus Collection

There are different ways to collect such a corpus: using available translation memories; asking customers for text samples; collecting internet texts, etc. In the current experiments, as such a text corpus, the set of documents was taken as produced by the PANACEA crawler; however only the monolingual source language documents were taken. As the ‘*Personal Translator*’ does not support XCES documents, all documents were converted into txt format beforehand, and a set of 23 files (each containing about 1000 sentences) was created.

##### Step 2: Unknown term detection

Then the unknown terms were identified by running file translations; the translations create a report which, among others, lists the unknown words (cf. fig. 3-1).

---

<sup>1</sup> Linatec: Fachwörterbuch Automobiltechnik. <http://www.linatec.de/products/tr/dict>

Statistics	
Count of unknown words :	234
Count of names :	509
Count of sentences :	1468
Count of sentences from translation memory :	0
Count of words in source text :	23368
Count of characters in source text :	160593
Count of words in target text :	29051
Count of characters in target text :	153106
Unknown words	
HHC, Sensorless, Wheel, Sway (2), kNm, Over (2), Vakuumstutzen, NAL, BSH (3), Rollover (2), VDM (4), Actuator, brin, Ethanolanteil, Überrollsensor, Plungerkolben, Sonthofen, boost (2), Energy (3), EN, Softgrip, ECE15 (5), Eco, Boost (2), TMC8 (4), AVH (2), E100 (2), Wäschepflege, Bremsweg*, and (6), Nfz (2), to, Rotordreh, ausserdem (2), Raffinierung, ZOH (2), GPA, zusammenspielt, Ansaugtrakt, Bifuel (4), Efficiency (5), PWG, Rotordrehvorrichtungen (2), H9, zyklendefeste, EGAS, SCR, Vice, Easy, Mixxo (2), Zero, bspw., MeRegio (2), for (2), fahrsituations, Common (7), Pilotsteller, GWEC, Kreisstrassen, FCM (4), BIR (2), RMF, ansteuerbaren, HBZ, Blower, Crashsensoren, Rails (3), TR3, Nm (3), Functions, US2010, Facility, Coriolis, tes, Torque (3), EGR (3), angeflanscht, Drehmomentenübertragung (3), Dynamics, nes, SIM (3), reversierende, eBike (2), Pedalgefühlssimulator, Laboratories, Mitigation (4), Gehäuseschalen (3), Verpol, Generatorfunktion (2), DF (2), Thermo, Zweikomponenten, Driving (2), communication, FPG2, DKG (3), shaken, Scientific, Packaging (3), KHD, Rotordrehvorrichtung (2), generatorische (3), ACC (2), DIH, Car (2), Harmonized, Powertrain, Rotordynamik, Fahrerinformationen, Movement, Deceleration, Electrical (2), Generatorbetrieb, Aplcnm, MW, Rekuperation, car, ASR (9), Hydraulic (2), Tire, Year, generatorisch (2), Injectors, Rail (11), Load (3), Vehicle (3), EcoFan, reversierender, TEV, onboard, Brake (3), Steer, z.B, Kavitationsschäden, Vectoring, BeMobility (2), Selective, wire, PWG12, PWG13, NEFZ (5), EVONIK, NEDC (6), Vacuum (3), Reversierantrieb, iwb, Parking, Non, ABS (16), FPC3, Compressed (2), Unit (9), ungelagert, Geo, gear, Momentensprung, Bühlertal, Aerotwin (2), Automated (3), Dynamic (7), Ansteuerelektronik, kürzestmöglichem, Evodium, Denoxtronic (2), Motronic (2), Hydro (4), infrastructure, Through (4), Tie (7), Catalytic, Gegenlenken, DV, sem, BHS (18), CNG (4), PWM (2), TD (3), D50, AHC, Ethanolanteile, AVR (2), verblendet (2), APB (3), Gefügestruktur, Bolt (4), Euro6, NSA (3), LiMotive (12), Injector (6), Convenience, CMMI, Crashverhalten, by, synthetisierter, prinzipbedingt, FlexFuel (2), CVT (7), sels, verhaltenem, Gasoline (3), Umformbarkeit, Rekuperationsanforderungen (2), EE, ROZ, Erdgaseinblasung, Bremsmomentenverblendung, Controlled, zinverbrauch, Motorzy, Dampfer, Reduction, ansteuerbare, Flexfuel, Massagiefunktion, Ramp, LiTec, Steering (2), generatorischen, hev (4), Stabilizer, Twin (2), mechatronische, Continuously, Perfektionierung, IPS21 (3), LIB (2), Bplcnm, Stoekicht, Active (3), Electronics (2), LWS (2), Rexroth (10), AirMax1, idler	
SmartCorrect™	
Anarbeitung→Abarbeitung	
erschliessen→erschließen	

Fig. 3-1 Result report of Unknown term search, below automatic spell correction (SmartCorrect)

Overall, 3800 unknown terms were identified, with frequency information. It should be noted that this procedure has two critical aspects:

1. only unknown single words are found; unknown multiwords are usually not identified;
2. the system only identifies terms with *no* translation; however the translation known by the system may be incorrect. This is a challenge especially in domain adaptation, as the system usually knows the general term meaning but not the domain-specific translation.

These aspects could be overcome by using term extraction tools which are text-based, not sentence-based as the unknown search is; such tools have been developed in the PANACEA framework.

### Step 3: Unknown term transfer lookup

The unknown terms need to be added to the system dictionary. The 3800 unknown terms were inspected, and the entries to be added to the dictionary were identified, as there are many candidates (spelling errors, acronyms etc.) which would not be added to a dictionary. 750 entries remained to be coded; they were assigned part-of-speech information (a feature required by the system for import).

So, for the 750 terms, translations needed to be found. To do this, several dictionaries and sources were used:

- the automotive dictionary cited above (36000 entries)
- a dictionary of one of Linguattec's automotive customers
- Linguadict, Linguattec's own dictionary ([www.linguadict.de](http://www.linguadict.de))
- special technical dictionary of Langenscheidt<sup>2</sup>
- internet sources (mainly [www.linguee.com](http://www.linguee.com))

Two people worked on the task of finding transfers.

<sup>2</sup> Langenscheidt: Fachwörterbuch Technik, [www.langenscheidt.de](http://www.langenscheidt.de)

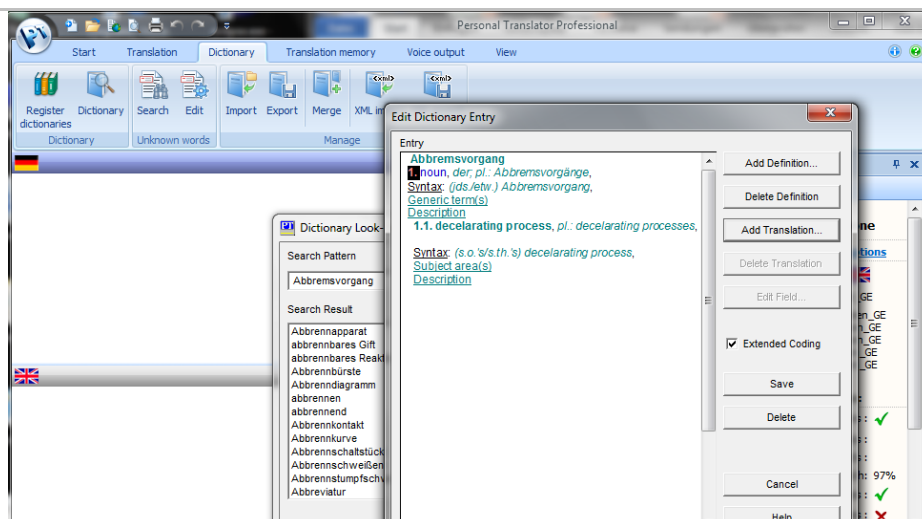


Fig. 3-2: 'Personal Translator' Coding Tool: Defaulted annotations for 'Abbremsvorgang -> deceleration process'. Users confirm, or change.

#### Step 4: Import terms into the PT dictionary

The final step is to import the terms plus their translations into the MT system. The import function of 'Personal Translator' has a powerful defaulting tool which defaults most of the features which the lexicon entry requires (like: inflection class, gender, subcategorisation). However in cases where this tool makes errors a human correction is required.

In the end, the system adaptation was done by creating a special glossary of automotive terms, based on coding unknown words in a corpus of domain-specific texts. This would be the conventional way of doing domain tuning.

#### Efforts for UNK system

In terms of efforts, the adaptation costs are:

Task	effort
Step 1: Prepare Corpus data	
preparing seed terms and seed URLs for the crawler	4 hrs (LT)
running the crawler, collecting the results	2 hrs (ILSP) (20 hrs machine time)
Step 2: Identify Unknowns	
find unknowns in the corpus sentences	--- (8 hrs machine time)
extract and merge the unknowns into a single list	1 hr in total
Step 3: Prepare unknowns for import	
select entries to be coded, add POS information	2 hrs
find translations for 750 words	21 hrs
Step 4: Import entries	
importing entries, correcting default annotations	3 hrs

Tab. 3-1: Efforts for UNK

Total adaptation time was 33 hrs. It should be noted that the first phase (corpus collection) was already done using PANACEA tools; alternative procedures could take more time. The critical issue, finding a

transfer and creating an MT entry from it, would take 26 hours, which is about 2 minutes per entry (2.08 minutes exactly, 3.25 person days). This is what current conventional system coding requires.

This result is in line with data for lexicon creation times in commercial systems, which range from 2 to 5 minutes per entry. The lower bound in the present experiment is due to the progress in the availability of internet tools which give much faster search results for translations of a term than 10 years ago.

Taking this value for the KFZ-Dictionary (system 1 above) would result in a coding time of 1250 hrs (156 person days) (assuming that the source term is already identified).

### 3.2 PANACEA Systems

The PANACEA systems are all corpus-based, and use tools to extract knowledge from the corpus data.

#### Baseline Systems

Two baseline systems are created: as a rule-based system, the Linguatrec ‘Personal Translator’ is used, just like in the previous experiments. For SMT, a Moses system was set up trained with the Europarl data for German-English.

#### Adaptation Workflows

To adapt the system, the processing chain is as follows (cf. fig. 3-3):

1. Run the PANACEA bilingual focused crawler, fed with seed URLs and seed terms. This results in a certain amount of parallel documents, in XCES format
2. Sentence-split and sentence-align these documents, extract parallel sentences, using the PANACEA toolbox. This results in a set of domain-specific sentence pairs
3. Use these in-domain data to train an SMT system for the automotive domain. This results in a domain-adapted SMT system, henceforth called ‘DCU’
4. Use the phrase table of the DCU system to create annotated glossaries for automotive terms which can be imported into a rule-based system. The glossary is extracted using PANACEA tools. This is imported into the MT and creates an adapted RMT system (henceforth called ‘GLO’).

A tool-based evaluation of these components is reported elsewhere (PANACEA D8.2), showing that the tools are compliant to industrial requirements.

#### Crawling

For crawling, the focused crawlers of ILSP were used. These crawlers need seed terms (in both languages) and seed URLs. These data were provided by Linguatrec, they can be found in the Annex.

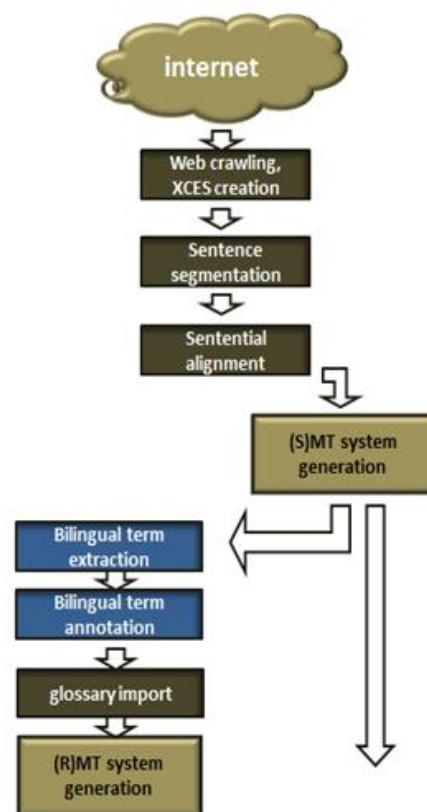


Fig. 3-3: PANACEA workflow

Crawling was done by ILSP<sup>3</sup>. The additional effort there for the automotive data was twofold:

1. To "enhance" the domain definition (terms and their weights). An initial MONO-crawl per language was done, "counting" the most common terms found, and reducing the weights of common terms (if they are "general"). The human effort is less than 1 hour, since there is no need to "watch" the crawler during crawling.
2. To have a look at the site (targeted per BILINGUAL crawl); create the text file with the seed URL. Actually, this took no more than 2 minutes per site.

Overall, the effort for crawling was:

Task	Effort
creation of seed terms and seed URLs	4 hrs
running the crawler	2 hrs (about 20 hrs machine time)

Tab. 3-2: Efforts for crawling

Crawling delivers the basic data for the system adaptation tasks<sup>4</sup>.

### 3.2.1 DCU system adaptation

#### *Data preparation*

Each parallel document output by the bilingual crawler is sentence-split. This is followed by the removal of duplicate sentences. Subsequently, the remaining sentences are then sentence-aligned.

The pairs of sentence-split parallel documents are sentence-aligned using Hunalign. This aligner provides a confidence score for each alignment. Following the procedure carried out in WP5, we keep those sentence pairs with confidence score above 0.4 (those were judged as being of good translation quality by native speakers, see D5.3.). The data is then tokenised and lowercased using Europarl tools.

The Table 3-3 gives details of the amount of sentences through the preparation process. „Provided“ is the amount of sentences output of the aligner without threshold. „Unique“ is the amount of sentences after removing duplicate sentence pairs. „Clean“ is the amount of sentences after applying the threshold, which removes those sentence alignments with confidence score below 0.4.

Dataset	Provided	Unique	%	Clean	%
Aut	24,235	18,786	77.52%	14,692	60.62%
WP5	13k-35k			10k-24k	66.5-77.8%

Table 3-3: Sentences for domain adaptation

Domain	Language	Set	Sentences	Tokens	Vocabulary	Type-token Ratio
AUT	DE	Train	14,692	276,133	26,498	9.60%
		Dev	500	5,979	2,374	39.71%
		Test	1,001	12,275	4,025	32.79%
	EN	Train	14,692	330,001	12,088	3.66%
		Dev	500	7,207	2,154	29.89%
		Test	1,001	14,376	3,254	22.63%

Table 3-4: Data sets for DCU training

<sup>3</sup> The PANACEA web service has limitations in crawling resources and time; therefore the crawling was done directly by ILSP.

<sup>4</sup> As already mentioned, these data were also used for the UNK adaptation described above.

Table 3-4 shows the amount of sentences in the development and test datasets. They come from the same dataset and the amount devoted to each set was decided taking into account the findings of Pecina et al., 2012 (more than 500 sentence pairs for development set does not provide a further improvement). Finally, the table also provides quantitative details of each of the datasets. For each of them we show the amount of sentences and tokens as well as the vocabulary size.

### ***DCU adapted SMT systems***

The MT systems used have been built using Moses (Koehn et al., 2007). For training the systems, training data is tokenized and lowercased using the Europarl tools. The original (non-lowercased) target sides of the parallel data are kept for training the Moses recaser. The lowercased versions of the target sides are used for training an interpolated 5-gram language model with Kneser-Ney discounting using the IRSTLM toolkit (Federico et al. 2011). Translation models are trained on the training corpora (see Section 2), lowercased and filtered on sentence level; we kept all sentence pairs having less than 100 words on each side. The maximum length of aligned phrases is set to 7 and the reordering models are generated using parameters: distance, orientation-bidirectional-fe. The model parameters are optimized by Minimum Error Rate Training (Och, 2003, MERT) on development sets. For decoding, test sentences are tokenized, lowercased, and translated by the tuned system. Letter casing is then reconstructed by the recaser and extra blank spaces in the tokenized text are removed in order to produce human-readable text.

A number of systems was built, according to the data used for training and tuning and the sentence aligner used to split this data:

The system **v0** is trained and tuned on Europarl, considered to be a general-domain corpus. This is the baseline system to which we will compare our domain-specific systems.

Systems **v1** are trained on the union of Europarl and the domain-specific data and tuned on domain-specific data.

Finally, systems **v2** are trained and tuned on domain-specific data only.

### ***Efforts for DCU system production***

The efforts to create the three DCU adapted systems are as follows<sup>5</sup>:

Task	Effort
Effort for crawling	cf. above
preparing the data	10 hrs
building and running SMT systems	10 hrs
documentation, training etc.	2 hrs

Tab. 3-5: Efforts for the DCU adaptation

This is in line with the efforts reported in Khalilov & Choudhury (2012) who reported 17 hrs effort per language direction.

<sup>5</sup> In fact, two SMT systems were built, one for the Health & Safety domain (task T8-2), and one for the Automotive domain (Task 8-3). The total amount of person hours devoted to the preparation, building and evaluation of SMT systems was 45 hours.

### 3.2.2 GLO system adaptation

The fourth system which was created was again a rule-based system, improved by a domain-specific glossary created from the parallel corpus as produced in PANACEA.

The tool used was taken from the PANACEA toolbox, called LT-P2G. It takes as input a phrase table as produced in the DCU system, and outputs a list of term candidates. This list is imported as special glossary into the '*Personal Translator*'.

It should be noted that the creation of terms here is independent of the PT dictionary, i.e. whether an entry is already in the PT dictionary or not. It avoids the two challenges of the UNK system, as it a. covers both single word and multiword terms, and b. provides translations related to the domain corpus, independent of the existence of the (source) term in the system lexicon.

Like in the KFZ and UNK systems, the GLO system adaptation consists of two steps:

- identification of (bilingual) term candidates, and
- import of these candidates into the MT system

#### *Step 1: Term Candidate Identification*

As just explained, term candidates are identified by running the P2G tool on the phrase tables of the adapted DCU system (v1)

##### First attempt

The P2G tool was run on the adapted DCU phrase table (v1), with a threshold of  $P(tl|sl)$  of 0.6. The result was a term candidate list of 101,400 entries. A first look into the data, sorted by frequency, showed that the majority of entries of the highest frequency was incorrect, so the data could not be simply used. Examples are given in fig. 3-4; the main reason is incorrect single word – multiword correspondences.

abgestimmter Bericht	report	No
Bericht Teile	report	No
Bericht zur Kenntnis	report	No
erstellter Bericht	report	No
herausgegebener Bericht	report	No
Reportage	report	No
veröffentlichter Bericht	report	No
Europäer	European	Ad
europäische Art	European	Ad
europäische Leistung	European	Ad
Quelle der Eu	European	Ad

Fig. 3-4: incorrect high-frequency candidates

##### Adaptation of the P2G extraction tool

Two improvement measures were taken to get a useful glossary: In addition to the probability  $P(tl|sl)$  of 0.6, term candidates must also meet the inverse relation  $P(sl|tl)$  of 0.6. Also, the frequencies of source and target term should be in a 'good' relation: Obviously, a term candidate with source frequency of 1000 and target frequency of 2 is not a good candidate pair.

To find out a sound relationship between source and target frequency, a glossary of automotive terms was extracted from the DCU v2 phrase table, and manually evaluated for errors. Then several extraction runs were made, restricting the distance in frequency from the arithmetic means of source and target frequency, from 20% (frequencies must be rather similar) to 90% (frequencies can be quite different). The idea is to increase precision by using more restrictive frequency distance. The result is shown in table 3-6.

Distance	entries	errors	precision	recall
no	2605	308	88,18	100,00
0.9	2444	240	90,18	93,82
0.8	2286	205	91,03	87,75
0.7	2127	184	91,35	81,65
0.6	1929	158	91,81	74,05
0.5	1605	136	91,53	61,61
0.4	1494	128	91,43	57,35
0.3	1248	112	91,03	47,91
0.2	1094	100	90,86	42,00

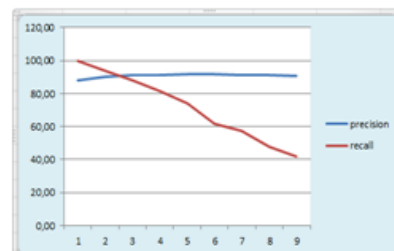


Table 3-6: recall and precision for different frequency distances

No restriction in difference creates a glossary of 2600 terms, the most restrictive measure the glossary is 1100 entries big. However, the reduction in recall does not improve precision; there is only an increase in precision if a 90% distance is used as opposed to no distance change at all. Too restricted frequency distance only reduces recall but does not increase precision.

The best compromise then seems to be to use a 0.9 distance threshold; it increases precision a bit, and reduces recall not so much.

### Second attempt

As a consequence of the tests with frequency, the P2G tool was re-run with  $P(t|s) = 0.6$ ,  $P(s|t) = 0.6$ , and  $FRQ_{distance} = 0.9$ . The run resulted in a term candidate list of about 35,100 entries<sup>6</sup>.

As such a candidate list will contain incorrect entries, the candidates with the highest frequency (all entries with frequency > 40) were inspected manually. Extraction quality is given in table 3-7.

errors		
nr types inspected	1270	
Moses errors	8	0.6%
P2G errors	124	9.7%
total errors	132	10.3%

Table 3-7: P2G quality

60% of the P2G errors are capitalisation errors (like: *Eu* instead of *EU*, *Fiat* instead of *FIAT*), due to gaps in the English proper name dictionary.

It should be noted that the inspection of only 1270 candidates is a fraction with regard to types, but the overwhelming majority with respect to tokens: Tab. 3-8 shows that a moderate effort can validate tokens with an enormous coverage.

coverage	total	inspected	in %
types	35100	1270	3.61%
tokens	2229838	2093283	93.8%

Table 3-8: Validation in types and tokens

<sup>6</sup> The main reduction effect compared to the first attempt (101000 candidates) is by using the P 0.6 for both directions.

This shows how efficient corpus-based terminology work can be: It allows to focus quickly on the frequent terms, and to neglect candidates which occur in texts so seldom that coding errors for such terms may have only minimal effect. In turn, if precision should be increased, this can most efficiently be done by working down the frequency-sorted candidate list.

### Step 2: Glossary import

Only entries with identical part-of-speech annotations can be imported into the ‘*Personal Translator*’; so about 500 term candidates were excluded from import.

Unlike the UNK system where only unknowns are imported, the GLO candidates can contain entries which are already in the system lexicon. The ‘*Personal Translator*’ offers two options for dictionary merging (aside from manually inspecting each entry):

- ‘*overwrite existing*’: always take the new entries
- ‘*keep existing*’: import only entries which are not known yet.

Both options were tried:

- GLO1 is a system where all 35,100 entries of the input list were added to the dictionary as additional lexicon
- GLO2 is a system where only the new (unknown) entries were added to the dictionary. The import with this option resulted in an additional dictionary of 12,900 entries. This means that 22,200 entries of the domain-adapted candidates (63%) were already known in the dictionary.

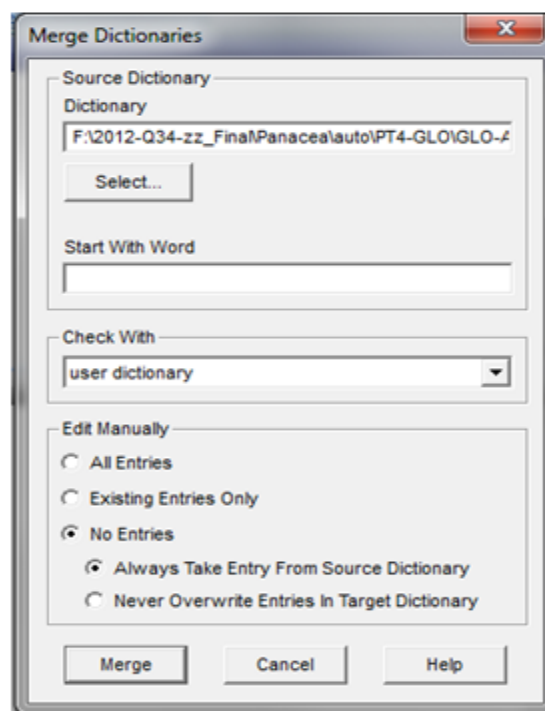


Fig. 3-5: MT Import options

For both variants, the import was done without inspecting the results of the defaulting process.

### Efforts for GLO system production

The effort to build an adapted GLO system was:

Task	Effort
effort to do the crawling of documents	(cf. above), plus
effort to produce the phrase tables in the DCU system	(cf. above)
run the term extractor	0.25 hrs
inspect the term results (1270 entries)	1.5 hrs
import the terms into the MT system	0.5 hrs

Tab. 3-9: Effort to produce the GLO systems

The critical time factor here is the inspection of the term candidates. The average effort is between 700 and 1000 entries per hour.

As mentioned, the import was not manually reviewed, unlike in the UNK case. Doing this would mean an effort of one hour per 150 to 200 entries. The defaulter is rather accurate, however, and the critical

cases are known beforehand (e.g. terms in plural form), and could be identified beforehand. Also, a validation component would help which identifies e.g. inflected forms produced by the defaulter in the corpus; if non-matching forms are found the defaulting may be wrong. Like in the case of term candidate inspection, the top 1270 candidates could be verified; this would mean an effort of 5 hrs; however this would be inefficient for the reasons just mentioned.

### 3.3 Adaptation efforts: Conclusion

The overall description of the different efforts for the different systems is given in table 3-10.

	non- PANACEA			PANACEA			
	workflow 1			workflow 2		workflow 3	
system	KFZ	UNK		DCU		GLO	
data collection	0	6	crawling	6	crawling	6	crawling
data preparation	0	1	find UNKs				
	0			10	prepar.align	10	prepar.,align
create transfer				10	GIZA/Moses	10	GIZA/Moses
correspondences		23	find transfers			0,5	find transfers
						1,5	validate list
create dictionary	0	3	import			0,5	import
total effort	0	33		26		28,5	
nr entries in dictionary	36000	750		n.a.		35100	
min./entry		1,84	(23 hrs)			0,04	(22 hrs)
effort for 1000 entries (hrs)		30,67				0,64	

Table 3-10: Overview of adaptation efforts

Conventional dictionary updating needed 33 hours for a 750 word dictionary, PANACEA tools needed 28.5 hours for a 35,000 word dictionary. The most significant difference is in transfer identification. The dictionary creation time needs to be excluded from the comparison, as in the UNK system the entries were verified, which did not happen in the GLO system, making the comparison a bit unbalanced in this respect. Defaulting aspects are treated in (Thurmair et al. 2012a).

Overall, if the total effort to create the translation resources (dictionaries or phrase table) is related to their size, then the PANACEA tools are clearly superior. If the effort to create 1000 entries of a dictionary is compared between the conventional way and the PANACEA tools then the PANACEA tools need 0.2% of the effort of a conventional procedure.

Of course, it must be said that in PANACEA not every entry is validated manually. However, it is an advantage of the PANACEA method that the risk of errors can be calculated, in terms of coverage, by using frequency information, and the probability of wrong entries causing errors in translation can be reduced to an acceptable limit without having to look at each single entry, simply by working down the frequency-sorted list, as long as time permits.

A comparison of translation output would show how relevant the potentially remaining errors are, i.e. if this non-validation of entries really deteriorates the results.

## 4 Quality Comparison

This section describes the changes in translation quality which the different adaptation techniques achieved. The methodology is to do a human comparison between the respective adaptation systems and their baselines. A test set of 1500 sentences, with one reference translation, was created for this task.

For the baseline translation, the ‘Personal Translator’ was used with the following settings:

- *no additional lexicon*
- *use decomposer = true*; this means that unknown words are decomposed, and translated compositionally; the effect of the switch is that OOV words are reduced from about 1030 to some 350
- *domain selection = automotive / technology* in case of translation conflicts

### 4.1 Non-PANACEA systems

For the non-Panacea systems, the full test set of 1500 sentences was used. They were translated with the baseline system (the ‘Personal Translator’), and then with the adapted system, and the two outputs were compared and evaluated using the Sisyphe-II-COMP tool.

#### 4.1.1 KFZ adapted system

Of the 1500 test sentences, 1024 were not changed by the KFZ add-on, and were translated the same way in both versions. The remaining 476 sentences have been compared manually, with the COMP tool. The result is shown in Tab. 4-1

System	KFZ-adapted vs. PT-baseline
total sentences evaluated	1500
improvements	152
deteriorations	159
equally good or bad	1189
improvement score <sup>7</sup>	-0.6%

Table 4-1: KFZ-adapted vs. PT-baseline

Surprisingly enough, there are just as many deteriorations as improvements; overall the translation quality has slightly deteriorated.

There are several reasons for this fact:

1. The PT system lexicon is rather large (more than 200.000 translations), and already contains many automotive terms. This fact increases the baseline quality. Sentences containing such terms cannot be improved any more by the additional glossary.

This fact also leads to a significant amount of synonyms (‘Hybridantrieb’ -> ‘hybrid drive’ vs. ‘hybrid propulsion’; ‘wirtschaftlich’ -> ‘cost-effective’ vs. ‘economical’; ‘robuste Konstruktion’ -> ‘robust design’ vs. ‘robust construction’). Such terms also do not lead to an improvement but to an ‘equally good/bad’ evaluation.

<sup>7</sup> calculated by: number improvements minus number deteriorations, divided by total sentences

In principle, the amount of quality improvement depends on the size and quality of the baseline lexicon.

2. Of course there are still improvements for terms where a specific term is provided for either a lexicon gap (*‘Polymerschaum’* -> *‘polymer foam’*) or a more general term (*‘Katalysator’* -> *‘catalytic converter’* instead of *‘catalyst’*; *‘gehärtete Welle’* -> *‘hardened shaft’* instead of *‘hardened wave’*); such cases form the bulk of improvements.

This is the behaviour which would be expected from adding a narrow-domain glossary.

3. Deteriorations mainly result from overspecifications, i.e. an automotive-specific term is used in a more general context (occurring also in automotive texts). Examples are:

- *‘fehlerhaft’* -> *‘faulty’* but *‘fehlerhafte Information’* -> *‘incorrect information’* (\**‘faulty information’*)
- *‘Rolle’* -> *‘roller’* but *‘führende Rolle’* -> *‘leading role’* (\**‘leading roller’*)
- *‘Rahmen’* -> *‘chassis’* but *‘(Polyurethan-) Rahmensysteme’* – *‘frame systems’* (\**‘chassis systems’*)
- *‘Brücke’* -> *‘jumper’* but *‘Spijkenisse Brücke’* -> *‘Spijkenisse bridge’* (\**‘Spijkenisse jumper’*)
- *‘Leitung’* -> *‘pipe’* but *‘Leitung der Firma’* -> *‘management of the company’* (\**‘pipe of company’*)
- *‘Mangel’* -> *‘fault’* but *‘Ingenieurmangel’* -> *‘lack of engineers’* (\**‘engineer fault’*)

Such cases indicate a structural shortcoming of conventional transfer selection strategies: It is incorrect to believe

- that entries of additionally loaded lexicons should always be preferred, or
- that entries of a specified specific domain should always be preferred.

Cases like the ones above show that there are more general readings of words mixed with more specific ones, even in narrow-domain texts, and the current selection strategies are clearly insufficient.

The consequence of that is to look for a more adequate transfer selection strategy, as has been done in the context of PANACEA WP5: ‘transfer selection’. Looking at larger units than just single words, and looking at conceptual contexts would be required to improve translation quality here, without deteriorations caused by overspecification.

#### 4.1.2 UNK adapted system

The second system, with the adapted UNKNOWNs dictionary, produced nearly the same results as the baseline: 1486 of the 1500 sentences came out identical. Table 4-2 gives the result:

System	UNK-adapted vs. PT-baseline
total sentences evaluated	1500
improvements	11
deteriorations	1
equally good or bad	1488
improvement score	0.66%

Table 4-2: UNK-adapted vs. PT-baseline

There is a marginal improvement, mainly because of the fact that some terms which were unknown before were covered in the adaptation. However, this relates only to a minor part of the OOV words (overall about 350 unknowns in the test set). For a good coverage, a significant effort would have to be assumed for this adaptation method.

## 4.2 PANACEA systems

The baseline for the DCU system and for the GLO system are different; so it is necessary to compare the two system adaptations to their baseline, but then also to compare the two baseline and the two adapted systems.

Of the 1500 test sentences, 500 were used as development set; so the number of test sentences here is 1000.

### 4.2.1 DCU adapted system

The DCU SMT system, adapted as described above, was compared to the baseline MOSES system. In Table 4-3, v0 refers to the MOSES baseline system, v2 refers to a system built only from in-domain data, and v1 refers to a system built from both baseline and in-domain data.

	BLEU	$\Delta\%$	NIST	$\Delta\%$	TER	$\Delta\%$	GTM	$\Delta\%$	OOV*	%
v0	0.1708		5.3161		0.7389		0.4071		1293	39.74%
v1	0.2146	<b>25.64%</b>	5.7956	<b>9.02%</b>	0.7123	<b>-3.60%</b>	0.4495	<b>10.43%</b>	986	<b>30.30%</b>
v2	0.1730	1.29%	5.0619	-4.78%	0.7549	2.17%	0.4055	-0.38%	2020	62.08%
google	0.3779	121.25%	8.0622	51.66%	0.5709	-22.74%	0.6000	47.40%	NA	NA
bing	0.3159	84.95%	7.3888	38.99%	0.6186	-16.28%	0.5471	34.41%	NA	NA
Best-WP5		32.6-70.7%		13.8-22.7%	NA		NA		NA	NA

Table 4-3: Automatic scores for SMT systems (v0-baseline, v1-adapted, v2-in-domain)

Automatic evaluation shows a relative increase of BLEU of about 25.6%, from 0.17 to 0.21.

Human evaluation of the two systems is given in table 4-4.

System	DCU-adapted vs. MOSES-baseline
total sentences evaluated	503
improvements	185
deteriorations	53
equally good or bad	265
improvement score	26.24%

Table 4-4: DCU-adapted vs. MOSES-baseline

The results show a significant improvement of the DCU system vis-à-vis the baseline system, in line with the BLEU indication. A difference of the SMT output, compared to the RMT output, is that only very few sentences came out identical.

### 4.2.2 GLO adapted system

As explained above, two additional dictionaries were created for the GLO system: one importing all entries found in the glossaries (about 35,000) (called GLO1 henceforth), and one importing only the missing / unknown entries (about 12,900 entries) (called GLO2 henceforth).

The results are given in tab. 4-5. While in GLO1 636 sentences came out identical, in GLO2 nearly all of them are identical (979).

System	GLO1 vs. PT-baseline	GLO2 vs. PT-baseline
total sentences evaluated	1000	1000
improvements	89	11
deteriorations	121	5
equally good/bad	790	984
improvement score	-4.05%	0.60%

Tab. 4-5: GLO (1/2) adapted vs. PT baseline

The deterioration in GLO1 is mainly due to defaulting errors: plural *\*informations* generated from lemma *information*, comparative *\*more farly* generated instead of *farther*, adverb *\*goodly* generated from *good*, and so on. In addition, the specificity errors already observed in the KFZ system are found here: ‘*Führungs- und Positionierungsanforderungen*’ (of a device) is not ‘*leadership requirements*’.

Defaulter technique usually assumes that all irregular entries are already covered in the dictionary, and correctly assumes that new entries follow regular patterns. This, however, is not the case, if irregular entries are overwritten in import, as it was done in GLO1.

The result for GLO2 is a bit surprising in that nearly all sentences were translated like in the baseline, although 12900 entries had been added to the dictionary. Other tests with the same language, same domain, nearly the same in-domain data set, same evaluation scenario, but different test set (ACCURAT scenario), had brought an increase in quality by 4.67% (cf. Thurmair et al. 2012b).

## 4.3 Comparisons

### 4.3.1 UNK vs. GLO

1. The lack of improvement for UNK and GLO is mainly due to a very strong baseline system. The ‘*Personal Translator*’ already contains a significant amount of automotive terms (as there are many customers in this domain):

- The import of the 35,100 GLO term list showed that 22,000 entries were already in the system;

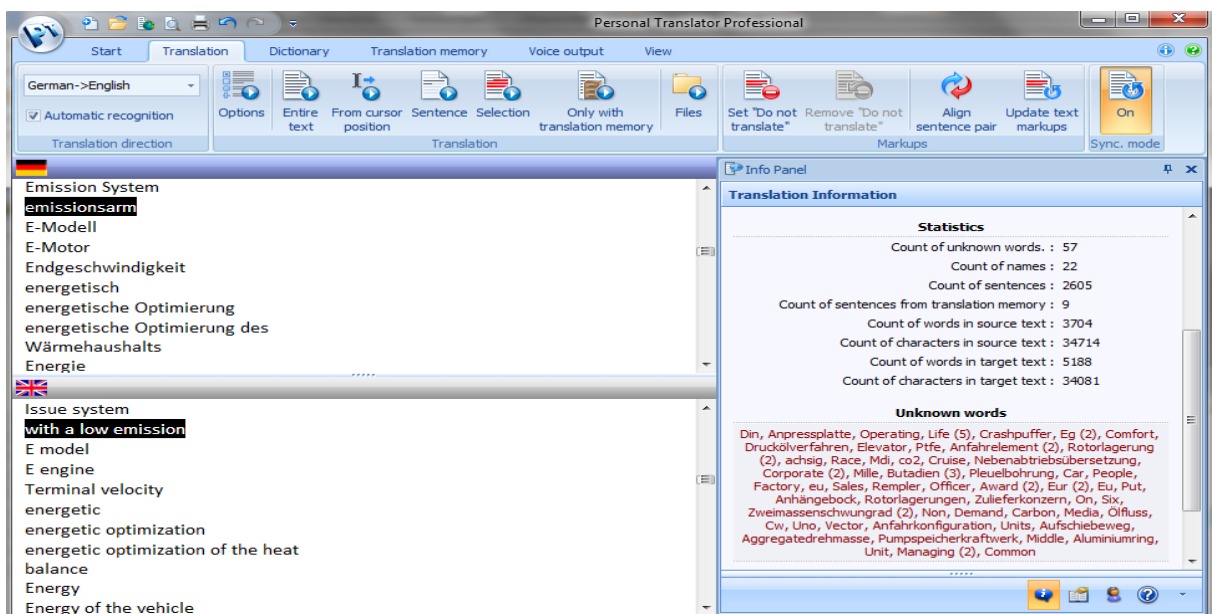


Fig. 4-1: Unknown search for the Automotive Glossary produced from DCU-v2

- Even if only the in-domain terms (DCU-v2, 2,600 terms) were compared with the system lexicon, there were only 57 terms the system could not cope with (cf. fig 4-1).

A strong baseline limits the possibility of system improvements.

2. A second observation is that the quality of the UNK and the GLO systems came out quite close, although the GLO dictionary contains entries which have not been manually validated. The extraction and import strategy developed in PANACEA does obviously not reduce translation quality.

However, the PANACEA strategy results in more than 40 times larger glossaries, which pays off in better coverage (same results in PANACEA tests, better results in ACCURAT tests).

#### 4.3.2 PT vs. MOSES, DCU vs. GLO

Finally, to evaluate if the additional effort of producing the GLO adaptation pays off in quality, a comparison of the GLO2 system with the DCU v1 adapted system was made. As this comparison is strongly influenced by the baseline of the two systems, a comparison of the baselines (PT vs. MOSES (i.e. DCUv0) was also made. For the comparison of the adapted systems, two testers were used. The results are shown in tab. 4-6.

System	DCUv0 vs. PT (baseline)	DCUv1 vs. GLO2 (adapted) tester 1	DCUv1 vs. GLO2 (adapted) tester 2
<b>total sentences evaluated</b>	506	500	506
<b>improvements in PT</b>	278	266	220
<b>deteriorations</b>	14	56	23
<b>equally good/bad</b>	214	178	263
<b>improvement score</b>	52.17%	42%	38.93%

Table 4-6: DCU vs. GLO, baseline and adapted

The table shows that there is a significant difference in the translation quality of the two baselines; it shows also that the quality gap reduces significantly for the adapted versions, but still about half of the sentences are better in the GLO system<sup>8</sup>.

If the output of the two systems is compared, the main differences in quality can be identified as follows:

- OOV words: The DCU system leaves many terms untranslated which the PT either has in its dictionary or is able to decompose. Example:

*<src> Eine Auswahl an Produkten für unser Benzin-Direkteinspritzsystem. </src>*

*<transl> A choice of products for our benzin-direkteinspritzsystem . </transl> // DCU*

*<transl2> A choice of products for our petrol direct injection system. </transl2> // PT*

- verb phrases: split verb constructions, verb particles are not composed properly. Example:

*<src> Wie schätzt BASF die Entwicklung des Gesamtjahres ein? </src>*

*<transl> As estimates BASF the development of the gesamtjahres ? </transl> // DCU*

*<transl2> How does BASF assess the development of the complete year? </transl2> // PT*

<sup>8</sup> To compute an inter-rater agreement is difficult in this context as both testers inspected 500 sentences, however not the same ones: The tool offers sentences out of a pool of 1000 test sentences in random order. However the evaluation results are similar.

Source	Zu unseren Kunden gehören Industrien wie Petrochemie, Pharmazie, Textilien, Lebensmittel und Landwirtschaft.
First Translation	Industries like petrochemistry, pharmacy, textiles, food and farming belong to our customers.
Second Translation	To our customers include industries such as petrochemie , pharmaceuticals , textiles , food and agriculture .

Fig. 4-2: Example comparison

- Constituent and word order. Example:

<src> Ende 2006 können die ersten Prototypen getestet werden. </src>

<transl> The end of 2006 the first prototype can be tested . </transl> // DCU

<transl2> The first prototypes can be tested at the end of 2006. </transl2> //PT

- Other phenomena like: do-insertion in questions, pronouns and such things (cf. fig. 4-2).

Also, it is not the case that SMT systems have no errors in transfer selection; if the training data contain several transfers then the decoder is able to mix them up occasionally.

A plausible explanation for the fact that SMT does worse in terms of OOV, compounds, verbs is that it doesn't have any module to deal with these "German-specific" phenomena, e.g. decomposer (Popovic et al. 2009) and reordering of main verbs (Niehues & Kolss 2009).

The final comparison is shown in fig. 4-3.

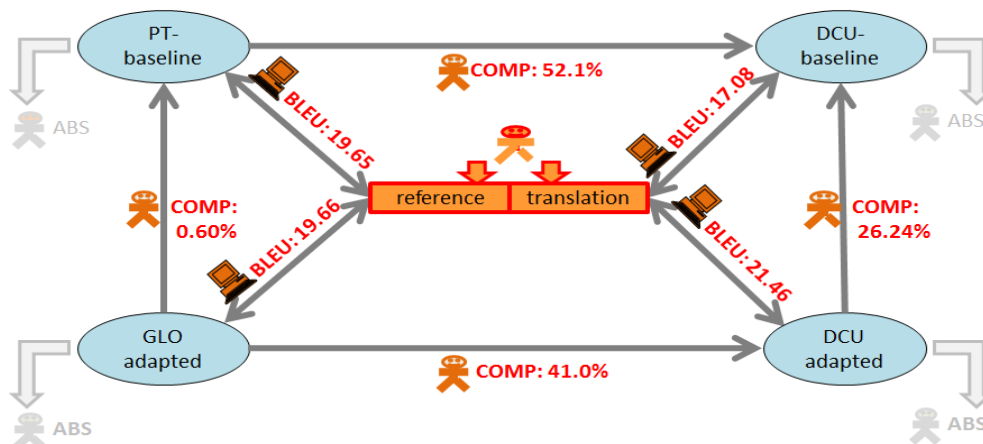


Fig. 4-3: Evaluation result GLO vs. DCU

### 4.3.3 Result

In terms of quality, the test results show that

- the rule-based non-PANACEA and PANACEA adaptations result in a similar quality, with PANACEA tools being superior if a different test set is taken.

The reasons for this fact are: 1. a very strong baseline system. 2. The failure of conventional transfer selection approaches to identify the best option in a given context.

- the statistical system improves significantly by the adaptations, however even the adapted version is quite away from the GLO adapted output.
- Although the BLEU score for GLO-adapted is lower, the system is far better than the DCU-adapted with higher BLEU score.

## 5 Conclusion

### 5.1 Result

The question to be answered was if the use of PANACEA tools would improve the domain adaptation task, either by producing superior quality, or by being more efficient than existing adaptation methods. The result of this report is the following:

1. In terms of effort, to produce a domain-adapted system with PANACEA tools is much more efficient than conventional procedures: To create a glossary of 1000 entries, the conventional method needs about 30 hours, with PANACEA tools need a bit more than 0.5 hours.
2. In terms of quality, the improved production efficiency has no negative effect on translation quality; both approaches show a marginal improvement over an already very strong baseline. In some tests, the PANACEA tools also produce superior translation quality.

### 5.2 Data

A special glossary was built from the automotive terms extracted from the DCU v2 system which contains in-domain data only; This should give better results than the DCU-v1 glossary, which would be rather administrative domain than automotive, as the baseline data are from Europarl and contain many EU-administrative terms.

The created glossary has about 2200 entries, and will be made available through METASHARE.

### 5.3 Outlook

1. Domain adaptation consists of two different tasks, and provides two productivity factors: One is to find translations for a given term, the second one is to annotate the term candidates for import and use in the MT system.

1a. The report has shown that PANACEA tools lead to a massive improvement in productivity in the area of transfer identification and bilingual term creation.

1b. The second area, creation of annotations / defaulting of entries, is of similar importance for the overall productivity: Efforts for UNK creation, as well as quality deteriorations in the GLO1 system show how important good defaulting is. PANACEA has looked into this area as well in WP 6 (subcategorisation frames, selection restrictions), and additional measures (like validation of defaulting proposals in a corpus) could be applied to increase defaulting precision.

The use of such results in current MT systems is limited, however, by the import capabilities of the different MT systems<sup>9</sup>, and therefore not easy to test in industrial contexts.

2. Once the additional domain-related terminology is imported into the dictionary, the task is not done yet. The more adaptations a system sees, the more relevant another challenge will be: Selection of best transfers from a set of transfer options.

It has been seen that existing techniques (like: always take the user entry; always take the domain-related entry) have only limited effect, and sometimes even deteriorate translation results (in case of the KFZ adaptation).

Therefore PANACEA made a special effort to look into transfer selection strategies in WP5, with promising results.

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<sup>9</sup> Many of them can not import annotations beyond simple part-of-speech information.

## 6 References

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## 7 Annex: Crawler Data

### 7.1 Seed terms DE

20:Alfa Romeo=automotive	100:Allshift=automotive	100:Drehmomentkapazität=automotive
20:Audi=automotive	100:Antriebsdrehzahl=automotive	100:Drehmomentsteuerung=automotive
20:Auto=automotive	100:Antriebsselement=automotive	100:Drehmomentwandler=automotive
20:Automobil=automotive	100:Antriebskette=automotive	100:Drehmomentwandlung=automotive
20:BMW=automotive	100:Antriebsleistung=automotive	100:Drehmomentwechsel=automotive
20:Citroen=automotive	100:Antriebsseite=automotive	100:Drehrichtung=automotive
20:Daimler=automotive	100:Antriebsstrang=automotive	100:Drehrichtungen=automotive
20:Fiat=automotive	100:Antriebswelle=automotive	100:Drehrichtungsumkehr=automotive
20:Ford=automotive	100:Ausgangsdrehzahl=automotive	100:Drehzahl=automotive
20:General Motors=automotive	100:Ausgangswelle=automotive	100:Drehzahlband=automotive
20:Honda=automotive	100:Ausgleichsgetriebe=automotive	100:Drehzahlbänder=automotive
20:Hyundai=automotive	100:Autogetriebe=automotive	100:Drehzahldifferenz=automotive
20:Kraftfahrzeug=automotive	100:Automatikgetriebe=automotive	100:Drehzahlen=automotive
20:LKW=automotive	100:Automatische Vorwählschaltung=automotive	100:Drehzahlfestigkeit=automotive
20:Lamborghini=automotive	100:Automatisches Getriebe=automotive	100:Drehzahlsteuerung=automotive
20:Mercedes=automotive	100:Automatisches Kupplungssystem=automotive	100:Drehzahlverhältnis=automotive
20:Mitsubishi=automotive	100:Automatisierte Schaltgetriebe=automotive	100:Drehzahlwechsel=automotive
20:Nissan=automotive	100:Automatisiertes Range-Splitter-Gruppen-Getriebe=automotive	100:Druckmittelgetriebe=automotive
20:Opel=automotive	100:Autotronic=automotive	100:Duallogic=automotive
20:PKW=automotive	100:Außenrad=automotive	100:Durashift=automotive
20:Peugeot=automotive	100:Axialkräfte=automotive	100:Easytronic=automotive
20:Porsche=automotive	100:Basis-Getriebe=automotive	100:Eingangsdrehzahl=automotive
20:Renault=automotive	100:C-Matic=automotive	100:Eingangswelle=automotive
20:SEAT=automotive	100:Continuously variable transmission=automotive	100:Einscheibenkupplung=automotive
20:Saab=automotive	100:Dauerfahrstellung=automotive	100:Elektrische Getriebe=automotive
20:Scania=automotive	100:Differentialgetriebe=automotive	100:Elektropneumatische Schaltung=automotive
20:Skoda=automotive	100:Doppelkupplung=automotive	100:Fahrzeuggetriebe=automotive
20:Subaru=automotive	100:Doppelkupplungsgetriebe=automotive	100:Fahrzeugschaltgetriebe=automotive
20:Toyota=automotive	100:Drehbewegung=automotive	100:Ferlec-Kupplung=automotive
20:VW=automotive	100:Drehmoment=automotive	
20:Volkswagen=automotive	100:Drehmomente=automotive	
20:Volvo=automotive		
100:2-Tronic=automotive		
100:4-Gang-Tiptronic=automotive		
100:6-Gang-Automatikgetriebe=automotive		
100:Abtrieb=automotive		
100:Abtriebsseite=automotive		
100:Abtriebswelle=automotive		

100:Feste Getriebe=automotive	100:Innenrad=automotive	100:Mittelachse=automotive
100:Flachriemen=automotive	100:Kardanwelle=automotive	100:Motor=automotive
100:Freilauf=automotive	100:Kegeln=automotive	100:Motordrehzahl=automotive
100:Freiläufen=automotive	100:Kegelradgetriebe=automotive	100:Motoren=automotive
100:Fünfgang-Getriebe=automotive	100:Keilriemen=automotive	100:Motorflansch=automotive
100:Ganghebel=automotive	100:Keilschubgetriebe=automotive	100:Motorsteuergerät=automotive
100:Gangrad=automotive	100:Kettengetriebe=automotive	100:MultiMode-Getriebe=automotive
100:Gangrädern=automotive	100:Kick-down=automotive	100:Multitronic=automotive
100:Gangwechsel=automotive	100:Kolbenmotor=automotive	100:Nachschaltgetriebe=automotive
100:Geschlossene Gehäuse=automotive	100:Koppelgetriebe=automotive	100:Neutral/Leerlauf=automotive
100:Getriebe=automotive	100:Kraftfahrzeugbau=automotive	100:Nockenwelle=automotive
100:Getriebe mit Wandlerschaltkupplung=automotive	100:Kraftfahrzeugen=automotive	100:Olymat=automotive
100:Getriebe mit Zahnradern=automotive	100:Kraftfahrzeuggetriebe=automotive	100:Opticruise=automotive
100:Getriebe-Steurelemente=automotive	100:Kraftschluss=automotive	100:Planetengetriebe=automotive
100:Getriebe-Steuerungseinheit=automotive	100:Kraftschlüssige Getriebe=automotive	100:Planetenräder=automotive
100:Getriebeausgangswellen=automotive	100:Kronenrad=automotive	100:Quickshift=automotive
100:Getriebeeingang=automotive	100:Kronenradgetriebe=automotive	100:Range-Getriebe=automotive
100:Getriebe=automotive	100:Kräften=automotive	100:Range-Splitter-Gruppen-Getriebe=automotive
100:Getriebewelle=automotive	100:Kupplung=automotive	100:Reibgetriebe=automotive
100:H-Schaltung=automotive	100:Kupplungskörper=automotive	100:Reibradgetriebe=automotive
100:H-Schaltungen=automotive	100:Kupplungspedal=automotive	100:Renngetriebe=automotive
100:Halbautomatische Getriebe=automotive	100:Kurbeltrieb=automotive	100:Rennsportgetriebe=automotive
100:Harmonic-Drive-Getriebe=automotive	100:Kurbelwelle=automotive	100:Riemengetriebe=automotive
100:Hauptwelle=automotive	100:Kurvengetriebe=automotive	100:Ritzel=automotive
100:Hondamatic-Getriebe=automotive	100:Kurvengetriebe mit Nutführung=automotive	100:Rollringgetriebe=automotive
100:Hycomat=automotive	100:Kurvengetriebe mit Zylinderkurve=automotive	100:Rtronic=automotive
100:Hydrak=automotive	100:Kurvengetriebe=automotive	100>Räderblock=automotive
100:Hydraulik=automotive	100:Lamellenbremsen=automotive	100:Rückwärtsgang=automotive
100:Hydraulikgetriebe Pneumatikgetriebe=automotive	100:Lamellenkupplung=automotive	100:Saxomat=automotive
100:Hydraulische Getriebe=automotive	100:Lamellenkupplungen=automotive	100:Schalt-Automatik=automotive
100:Hydraulisches Getriebe=automotive	100:Leerlauf=automotive	100:Schaltelement=automotive
100:Infinitely Variable Transmission=automotive	100:Leistungsteilungsgetriebe=automotive	100:Schaltelemente=automotive
	100:Lenkstockhebel=automotive	100:Schalten=automotive
	100:Lineartronic=automotive	100:Schaltgabeln=automotive
	100:Magnetpulverkupplung=automotive	100:Schaltgasse=automotive
	100:Mehrwellengetriebe=automotive	100:Schaltgeschwindigkeit=automotive
		100:Schaltgetriebe=automotive
		100:Schalthebel=automotive
		100:Schaltknäuf=automotive
		100:Schaltkupplung=automotive

100:Schaltmuffe=automotive	100:Umlaufgetriebe.=automotive	100:automatisierten Getriebe=automotive
100:Schaltprogramm=automotive	100:Untersetzungsverhältnis=automotive	100:automatisiertes Schaltgetriebe=automotive
100:Schaltstufen=automotive	100:Variomatic=automotive	100:axiales Verschieben=automotive
100:Schaltvorgang=automotive	100:Ventile=automotive	100:e-Gear=automotive
100:Schaltwelle=automotive	100:Ventilflattern=automotive	100:elektrohydraulisch=automotive
100:Schieberadgetriebe=automotive	100:Verbrauchsoptimierung=automotive	100:elektromagnetisch=automotive
100:Schmierung=automotive	100:Verbrennungsmotor=automotive	100:elektronisch- hydraulisch=automotive
100:Schneckengetriebe=automotive	100:Verbrennungsmotoren=automotive	100:elektronische Getriebe=automotive
100:Schraubengetriebe=automotive	100:Verstellgetriebe=automotive	100:elektronische Schaltung=automotive
100:Schraubenradgetriebe=automotive	100:Verteilergetriebe=automotive	100:elektronischen Regelung=automotive
100:Schubkettengetriebe=automotive	100:Verzahnung=automotive	100:elektronischer Getriebesteuerungen=automotive
100:Sechsgang- Getriebe=automotive	100:Viergang-Getriebe=automotive	100:geschlossen Getriebe=automotive
100:Selespeed=automotive	100:Vorgelegewelle=automotive	100:halbautomatischen Getriebe=automotive
100:SensoDrive=automotive	100:Vorschaltgetriebe=automotive	100:hochschaltenden=automotive
100:Sequentielle Getriebe=automotive	100:Wandler- Automatikgetriebe=automotive	100:hydraulisch=automotive
100:Softtip=automotive	100:Wandler- Automatikgetriebe=automotive	100:hydraulischer Aktuatorik=automotive
100:Softtouch=automotive	100:Wandlerschaltkupplung=automotive	100:hydro-pneumatischer Baugruppe=automotive
100:Spezialgetriebe=automotive	100:Wechselgetriebe=automotive	100:hydrodynamisches Getriebe=automotive
100:Sportomatic=automotive	100:Wechseln der Übersetzungen=automotive	100:hydrostatisch=automotive
100:Sprintshift=automotive	100:Welle=automotive	100:i-Shift=automotive
100:Stirnrad=automotive	100:Wellen=automotive	100:koaxial=automotive
100:Stirnradgetriebe=automotive	100:Wellenachse=automotive	100:manuelles Schalten des Automatikgetriebes=automotive
100:Strömungsgetriebe=automotive	100:Wählhebel=automotive	100:mechanische Getriebe=automotive
100:Stufenlose Getriebe=automotive	100:Wälzkörpergetriebe=automotive	100:mechanische Wandlerüberbrückung=automotive
100:Synchronisation=automotive	100:Zahnradgetriebe=automotive	100:parallel=automotive
100:Synchronisationsringe=automotive	100:Zahnradpaare=automotive	100:pneumatisch=automotive
100:Taumelradgetriebe=automotive	100:Zahnradstufe=automotive	100:selbstlernende Automatikgetriebe=automotive
100:Telligent- Schaltung=automotive	100:Zahnradstufen=automotive	100:stufenlose Getriebe=automotive
100:TipMatic=automotive	100:Zahnradsätze=automotive	
100:Tiptronic-Gasse=automotive	100:Zahnriementrieb=automotive	
100:Transfluide=automotive	100:Zahnräder=automotive	
100:Triebwellen- Ausgang=automotive	100:Zugmittelgetriebe=automotive	
100:Trockenkupplung.=automotive	100:Zusätzliche Getriebe=automotive	
	100:Zykloidgetriebe=automotive	

100:synchronisierten Getriebe=automotive	100:zugkraftunterbrechungsfreien Schaltvorgang=automotive	-100:Kraftrad=automotive
100:unsynchronisierten Getriebe=automotive	100:Übersetzung=automotive	-100:Motorrad=automotive
100:vollautomatischen Getriebe=automotive	100:Übersetzungsstufen=automotive	-100:Schiff=automotive
100:zugkraftunterbrechungsfrei=automotive	100:Übersetzungsverhältnisse=automotive	-100:Boot=automotive
	-100:Fahrrad=automotive	-100:Eisenbahn=automotive
	-100:Flugzeug=automotive	-100:Lok=automotive
		-100:Lokomotive=automotive

## 7.2 Seed terms EN

20:Alfa Romeo=automotive	100:Geartronic=automotive	100:clutch=automotive
20:Audi=automotive	100:H-pattern=automotive	100:clutch brake=automotive
20:car=automotive	100:H-pattern automotive transmissions=automotive	100:clutch disk=automotive
20:automobile=automotive	100:Hondamatic=automotive	100:clutch packs=automotive
20:BMW=automotive	100:Hydra-Matic=automotive	100:clutch-brake=automotive
20:Citroen=automotive	100:Manumatic=automotive	100:clutches=automotive
20:Daimler=automotive	100:Saxomat=automotive	100:clutching mechanism=automotive
20:Fiat=automotive	100:AMG speedshift MCT=automotive	100:clutchless manual transmission=automotive
20:Ford=automotive	100:automated manual transmission=automotive	100:column mounted gear shift lever=automotive
20:General Motors=automotive	100:automated transmission=automotive	100:column shifters=automotive
20:Honda=automotive	100:automated transmissions=automotive	100:column-mounted shifter=automotive
20:Hyundai=automotive	100:automatic gearbox=automotive	100:combustion engine=automotive
20:truck=automotive	100:automatic transmission=automotive	100:compound epicyclic planetary gearset=automotive
20:lorry=automotive	100:automatic transmission families=automotive	100:computerized transmissions=automotive
20:Lamborghini=automotive	100:automatic transmission fluid=automotive	100:cone clutch=automotive
20:Mercedes=automotive	100:automatic transmission models=automotive	100:console-mounted shifter=automotive
20:Mitsubishi=automotive	100:automobile transmissions=automotive	100:constant mesh gear sets=automotive
20:Nissan=automotive	100:automotive automatic transmissions=automotive	100:constant-mesh gearboxes=automotive
20:Opel=automotive	100:axial PTO shaft=automotive	100:continuous variable transmissions=automotive
20:Peugeot=automotive	100:balk rings=automotive	100:continuously variable transmission=automotive
20:Porsche=automotive	100:balk rings=automotive	100:continuously variable transmissions=automotive
20:Renault=automotive	100:blocker rings=automotive	100:countershaft=automotive
20:SEAT=automotive	100:brake bands=automotive	100:countershafts=automotive
20:Saab=automotive	100:cast iron case=automotive	
20:Scania=automotive		
20:Skoda=automotive		
20:Subaru=automotive		
20:Toyota=automotive		
20:VW=automotive		
20:Volkswagen=automotive		
20:Volvo=automotive		
100:7G-Tronic=automotive		
100:Easytronic=automotive		

100:coupling device=automotive	100:electronically-controlled	100:gears=automotive
100:crankshaft=automotive	CVT=automotive	100:gearshift=automotive
100:crash box=automotive	100:engine crankshaft=automotive	100:gearshift knob=automotive
100:cross-breed	100:engine speed=automotive	100:gearshift lever=automotive
transmission=automotive	100:engine torque=automotive	100:general motors
100:design variations=automotive	100:engine's flywheel=automotive	produced=automotive
100:diagonal cut helical gear	100:engine's output=automotive	100:high torque=automotive
sets=automotive	100:epicyclic differential gear	100:hydraulic=automotive
100:differential=automotive	system=automotive	100:hydraulic automatic
100:differentials=automotive	100:epicyclic differential	transmission=automotive
100:direct shift gearbox=automotive	gearing=automotive	100:hydraulic automatic
100:direct-shift gearbox=automotive	100:epicyclic gear	transmissions=automotive
100:direction of rotation=automotive	system=automotive	100:hydraulic control
100:dog clutch=automotive	100:epicyclic gearing=automotive	center=automotive
100:dog clutch selector=automotive	100:external overdrive=automotive	100:hydraulic motor=automotive
100:dog-leg first shift	100:final drive shaft=automotive	100:hydraulic pump=automotive
pattern=automotive	100:five-speed gearbox=automotive	100:hydraulic servos=automotive
100:double clutching=automotive	100:floor-mounted	100:hydraulics=automotive
100:double-clutching=automotive	shifter=automotive	100:hydrodynamic=automotive
100:drive train=automotive	100:fluid coupling=automotive	100:hydrodynamic
100:drive wheels=automotive	100:fluid coupling/torque	transmission=automotive
100:driver-operated	converter=automotive	100:hydrostatic drive=automotive
clutch=automotive	100:fluid flywheel=automotive	100:hydrostatic
100:driveshaft=automotive	100:front-wheel-drive transaxle's ring	transmission=automotive
100:dual clutch=automotive	gear=automotive	100:hydrostatic
100:dual clutch	100:fuel efficiency=automotive	transmissions=automotive
transmission=automotive	100:gear=automotive	100:idler shaft=automotive
100:dual-clutch=automotive	100:gear clash=automotive	100:infinitely variable
100:dual-clutch	100:gear configuration=automotive	transmission=automotive
transmission=automotive	100:gear lever=automotive	100:input shaft=automotive
100:dynaflow	100:gear pump=automotive	100:layshaft=automotive
transmission=automotive	100:gear ratio=automotive	100:lock-up torque
100:electric power=automotive	100:gear ratios=automotive	converter=automotive
100:electric transmission=automotive	100:gear reduction=automotive	100:locking collar=automotive
100:electric transmission	100:gear selector=automotive	100:lubricating oil=automotive
capacity=automotive	100:gear shift types=automotive	100:main bearing=automotive
100:electric variable	100:gear stick=automotive	100:mainshaft=automotive
transmission=automotive	100:gear teeth=automotive	100:manual gearbox=automotive
100:electrical adjustable-speed	100:gear variety=automotive	100:manual transmission=automotive
drives=automotive	100:gear/belt	100:manual
100:electrical path=automotive	transmissions=automotive	transmissions=automotive
100:electro-mechanical	100:gearbox=automotive	100:manually controlled automatic
servos=automotive	100:gearboxes=automotive	transmissions=automotive
100:electrohydraulic	100:gearchange=automotive	100:mechanical clutch=automotive
transmission=automotive		100:mechanical path=automotive

100:mechanical power=automotive	100:rear-wheel drive=automotive	100:standard
100:motor crankshaft=automotive	100:rear-wheel-drive	transmission=automotive
100:motor vehicles=automotive	transmission=automotive	100:straight-cut spur gear
100:multi-functional	100:regulating torque	sets=automotive
clutch=automotive	transfer=automotive	100:synchro ring=automotive
100:multi-ratio transmission	100:reverse gear=automotive	100:synchro-less dog-clutch
systems=automotive	100:rotate=automotive	engagement mechanism=automotive
100:multiple gear ratios=automotive	100:rotates slightly=automotive	100:synchromesh=automotive
100:multiple-turbine torque	100:rotating power	100:synchromesh box=automotive
converter=automotive	source=automotive	100:synchromesh dog
100:non-slip coupling=automotive	100:rotational speed=automotive	clutch=automotive
100:non-synchromesh	100:rotational speeds=automotive	100:synchromesh
transmission=automotive	100:semi-automatic	gearbox=automotive
100:non-synchronised=automotive	transmission=automotive	100:synchromesh
100:non-synchronous	100:semi-automatic	systems=automotive
transmission=automotive	transmission.=automotive	100:synchromesh
100:non-synchronous	100:semi-automatic	transmission=automotive
transmissions=automotive	transmissions=automotive	100:synchronised gear
100:output pinion	100:semi-manual	box=automotive
meshing=automotive	transmissions=automotive	100:synchronised
100:output shaft=automotive	100:sequential manual	transmission=automotive
100:overdrive gear=automotive	transmission=automotive	100:synchronization
100:overdrive gears=automotive	100:sequential shifting=automotive	mechanism=automotive
100:paddle shifter=automotive	100:sequential	100:synchronized=automotive
100:planetary gear=automotive	transmissions=automotive	100:synchronized
100:planetary gear	100:shaft=automotive	gearing=automotive
rotations=automotive	100:shaft and gear	100:synchronized
100:planetary gear	configuration=automotive	transmissions=automotive
system=automotive	100:shaft configuration=automotive	100:synchronizer=automotive
100:planetary gearing=automotive	100:shafts=automotive	100:synchronizer rings=automotive
100:planetary gearset=automotive	100:shift pattern=automotive	100:torque=automotive
100:power split	100:shift stick=automotive	100:torque conversion=automotive
transmission=automotive	100:shifter=automotive	100:torque converter=automotive
100:power	100:shifting gears=automotive	100:torque converter
transformation=automotive	100:single-ratio	automatic=automotive
100:power-split epicyclic differential	transmissions=automotive	100:torque converter
gearing system=automotive	100:sliding mesh	housing=automotive
100:powershift gearbox=automotive	transmissions=automotive	100:torque converter lock-up
100:prime mover output	100:sliding-mesh=automotive	clutch=automotive
shaft=automotive	100:slippage=automotive	100:torque converters=automotive
100:prop shaft=automotive	100:speed conversion=automotive	100:torque output=automotive
100:range-splitter	100:speed/torque	100:transformation=automotive
transmissions=automotive	adaptation=automotive	100:transforms=automotive
100:ratio selectability=automotive	100:splitter transmissions=automotive	100:transmission=automotive
100:rear axle=automotive	100:stall speed=automotive	100:transmission
100:rear wheel drive cars=automotive		assembly=automotive

100:transmission control unit=automotive	100:unsynchronized transmission=automotive	-100:motorcycle=automotive
100:transmission designs=automotive	100:unsynchronized transmissions=automotive	-100:aircraft=automotive
100:transmission input=automotive	100:valve body=automotive	-100:ship=automotive
100:transmissions=automotive	100:wheel speed=automotive	-100:boat=automotive
100:unsynchronized / non- synchronous system=automotive	100:zeroshift=automotive	-100:railway=automotive
100:unsynchronized gearing=automotive	-100:airplane=automotive	-100:rail=automotive
	-100:bicycle=automotive	

### 7.3 Seed URLs

<a href="http://www.voith.com">http://www.voith.com</a>	5	<a href="http://www.truckparts.org">http://www.truckparts.org</a>	5
<a href="http://www.bhs-getriebe.de">http://www.bhs-getriebe.de</a>	5	<a href="http://www.thetruckstop.us">http://www.thetruckstop.us</a>	5
<a href="http://www.voithturbo.com">http://www.voithturbo.com</a>	5	<a href="http://www.burtonpower.com">http://www.burtonpower.com</a>	5
<a href="http://www.getriebetechnik-schaefer.de">http://www.getriebetechnik-schaefer.de</a>	5	<a href="http://www.gearboxman.co.uk">http://www.gearboxman.co.uk</a>	5
<a href="http://www.bhs.gearbox-service.com">http://www.bhs.gearbox-service.com</a>	5	<a href="http://www.enginesandgearboxes.co.uk">http://www.enginesandgearboxes.co.uk</a>	5
<a href="http://www.voith.de">http://www.voith.de</a>	5	<a href="http://www.autoblog.com">http://www.autoblog.com</a>	5
<a href="http://www.getrag.de">http://www.getrag.de</a>	5	<a href="http://www.ford.com">http://www.ford.com</a>	5
<a href="http://www.luk.de">http://www.luk.de</a>	5	<a href="http://www.motoringfile.com">http://www.motoringfile.com</a>	5
<a href="http://www.zf.com">http://www.zf.com</a>	5	<a href="http://www.jatco.co.jp">http://www.jatco.co.jp</a>	5
<a href="http://www.automobil-produktion.de">http://www.automobil-produktion.de</a>	5	<a href="http://www.allisontransmission.com">http://www.allisontransmission.com</a>	5
<a href="http://www.eaton-getriebe.de">http://www.eaton-getriebe.de</a>	5	<a href="http://www.fiat.com">http://www.fiat.com</a>	5
<a href="http://www.manted.de">http://www.manted.de</a>	5		
<a href="http://www.volkswagen.de">http://www.volkswagen.de</a>	5		
<a href="http://www.motor-talk.de">http://www.motor-talk.de</a>	5		
<a href="http://www.kfztech.de">http://www.kfztech.de</a>	5		
<a href="http://www.auto-motor-und-sport.de">http://www.auto-motor-und-sport.de</a>	5		
<a href="http://www.automobil-produktion.de">http://www.automobil-produktion.de</a>	5		
<a href="http://www.autoplenum.de">http://www.autoplenum.de</a>	5		
<a href="http://www.volkswagenag.com">http://www.volkswagenag.com</a>	5		
<a href="http://www.bmw.de">http://www.bmw.de</a>	5		
<a href="http://www.bmw.com">http://www.bmw.com</a>	5		
<a href="http://www.bmw-syndikat.de">http://www.bmw-syndikat.de</a>	5		
<a href="http://www.bwauto.com">http://www.bwauto.com</a>	5		
<a href="http://www.borgwarner.com">http://www.borgwarner.com</a>	5		
<a href="http://www.velar.de">http://www.velar.de</a>	5		
<a href="http://www.thegearbox.org">http://www.thegearbox.org</a>	5		
<a href="http://www.involutetools.com">http://www.involutetools.com</a>	5		
<a href="http://www.thecartech.com">http://www.thecartech.com</a>	5		
<a href="http://www.gears-gearbox.com">http://www.gears-gearbox.com</a>	5		
<a href="http://www.aisin.com">http://www.aisin.com</a>	5		