Abstract

The paper presents two techniques for lemmatization of Polish person names. First, we apply a rule-based approach which relies on linguistic information and heuristics. Then, we investigate an alternative knowledge-poor method which employs string distance measures. We provide an evaluation of the adopted techniques using a set of newspaper texts.

1 Introduction

Proper names constitute a significant part of natural language texts (estimated to about 10% in newspaper articles) and are important for NLP applications, such as Information Extraction, which rely on automatic text understanding.\footnote{The research presented in this paper was partially founded by the Ministry of Education and Science (Poland), grant number 3T11C00727.} In particular, coreference resolution (e.g., identifying several name variants as referring to the same entity) plays a crucial role in such systems. Although automatic recognition of proper names in English, French and other major languages has been in the research focus for over a decade now, cf. (Bikel et al., 1997), (Borthwick, 1999), (Li et al., 2003), only a few efforts have been reported for Slavic languages, cf. (Cunningham et al., 2003) (Russian and Bulgarian), (Piskorski, 2005) (Polish). Rich inflection and a more relaxed word order make recognition of proper names in Slavic more difficult than for other languages. Moreover, inflection of proper names is usually quite different from common nouns, which complicates the lemmatization process necessary for correct coreference resolution. In this paper, we focus on lemmatization of Polish person names, the most idiosyncratic class of proper names in this language. First, we report results of a rule-based symbolic approach. We apply different heuristics, mostly based on the internal (morphological and syntactic) structure of proper names but also on the surrounding context. Sometimes, however, the required information is not available, even if the entire document is considered, and lemmatization cannot be performed. Therefore, we experimented with various knowledge-poor methods, namely string distance metrics, in order to test their usefulness for lemmatization of Polish person names as an alternative technique, especially for cases where document-level heuristics are insufficient.

Lemmatization of proper names in Slavic has not attracted much attention so far but some work has been done for Slovene: (Erjavec et al., 2004) present a machine-learning approach to lemmatization of unknown single-token words, whereas (Pouliquen et al., 2005) report on a shallow approach to find base forms.

The organization of the paper is as follows. First, we present a description of phenomena which make lemmatization of Polish person names a difficult task. Next, a rule-based approach and its evaluation are presented. Then, various string distance metrics are introduced, followed by the results of experiments on newspaper texts. The final section presents conclusions and perspectives for future work.
Table 1: Declension of Polish male vs. female names

| case | male name     | female name    |
|------|---------------|----------------|
| nom  | Kazimierz Polak | Kazimiera Polak |
| gen  | Kazimierz Polaka | Kazimiera Polak  |
| dat  | Kazimierzowi Polakowi | Kazimierze Polak |
| acc  | Kazimierza Polaka | Kazimierza Polak |
| ins  | Kazimierzem Polakiem | Kazimierza Polak |
| loc  | Kazimierzu Polaku | Kazimierze Polak |
| voc  | Kazimierzu Polaku | Kazimierza Polak |

Table 2: Common noun vs. person name inflection

| case | sg   | pl   |
|------|------|------|
| nom  | goląb | Goląb |
| dat  | goląbowi | Goląbowi |
| acc  | goląbia | Goląbia |
| ins  | goląbiem | Goląbiem |
| loc  | goląbiu | Goląbiu |
| voc  | goląbiu | Goląbiu |

2 Declension Patterns of Polish Person Names

Polish is a West Slavic language with rich nominal inflection: nouns and adjectives are inflected for case, number and gender. There are 7 cases, 2 numbers and traditionally 3 genders are distinguished: masculine, feminine and neuter. Just like common nouns, Polish person names undergo declension but their inflectional patterns are more complicated. A typical Polish name consists of a first name and a last name; unlike in Russian or Bulgarian, there are no patronymics. Additionally, titles (e.g., dr ‘Phd’, inż. ‘engineer’, prof. ‘professor’) or honorific forms (pan ‘Mr.’ or pani ‘Mrs./Miss’) are often used. In general, both the first and the last name can be inflected, e.g., Jan Kowalski (nominative) vs. Jana Kowalskiego (genitive/accusative). If the surname is also a regular word form, things get more complicated. Whether the last name can be inflected in such cases depends on several factors, e.g., on the gender of the first name, a category (part-of-speech) and gender of the (common) word used as a surname. For instance, if the surname is a masculine noun, it is inflected only if the first name is also masculine. This is illustrated in Table 1 with declension of the male name Kazimierz Polak ‘Casimir Pole’ and its variant with the female first name Kazimierka.

If the surname is an adjective (e.g., Niski ‘Short’), it is inflected (according to the adjectival paradigm) and agrees in gender with the first name, i.e., male and female last name forms are different (e.g., Niski ‘Short’ (masc.) vs. Niska ‘Short’ (fem.)). The declension of foreign surnames may strongly depend on their origin, and in particular on the pronunciation. For example, the name Wilde is pronounced differently in English and German, which impacts its declension in Polish. If it’s of English origin, a nominal declension is applied, i.e., Wilde’a (gen.).

whereas if it comes from German, an adjective-like declension is adopted: Wildego (gen.).

Declension of surnames which are also common nouns can be different from the declension of common nouns. In Table 2, we present a comparison of the common noun goląb ‘dove’ in singular and plural with the corresponding forms used for the surname. A comprehensive overview of this rather intriguing declension paradigm of Polish names is given in (Grzenia, 1998).

Finally, first name forms present problems as well. Foreign masculine first names, whose pronounced version ends in a consonant or whose written version ends in -a, -o, -y or -i do in general get inflected (e.g., Jacques (nom.) vs. Jacques’a (gen./acc.)), whereas names whose pronounced version ends in a vowel and are stressed on the last syllable (e.g., François) usually do not change form. For female first names created from a male first name, e.g., Józef (masc.) vs. Józefa (fem.), there is a frequent homonymy between the nominative form of the female name and the genitive/accusative form of the corresponding male form, e.g., Józefa is nominative of Józef (fem.) and genitive/accusative of Józef (masc.).

3 Rule-Based Approach to Person Name Lemmatization

3.1 Experiment

Our rule-based approach to person name lemmatization exploits existing resources (a dictionary of first names and contextual triggers) and relies on contextual information (heuristics). It has been implemented using SProUT, a shallow processing platform, integrated with a Polish morphological anal-

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2The declension of such surnames depends on the local tradition and sometimes can be identical with the pattern used for common nouns.
yser (Piskorski et al., 2004). For first names, all in-
flected forms of the most frequent Polish first names
are stored in a database so a simple gazetteer look-up
associates names with the corresponding base form.
We also used a list of ca 30 000 foreign first names
(nominaive forms). For last names, we applied se-
veral heuristic rules in order to recognize and produce
their base forms. First, we identify most common
types of Polish surnames, e.g., capitalized words
ending in -skiego, -skim, -skiemu or -icza, -iczem, -
iczu (typical last name suffixes), and convert them to
the corresponding base forms (i.e., words ending in
-ski and -icz, respectively). In this way, a significant
number of names can be lemmatized in a brute-force
manner.

For all remaining surnames, more sophisticated
rules have to be applied. As discussed in sec. 2,
these rules have to take into account several pieces
of information such as part-of-speech and gender of
the (common) word which serves as a surname,
but also gender of the first name. The major prob-
lem we encountered while applying these rules is
that the information necessary to trigger the appro-
priate rule is often missing. For example, in sen-
tence (1), inferring gender of the surname/first name
could involve a subcategorization frame for the verb
powiadamie ‘inform’, which requires an accusative
NP argument. In this way we might possibly predict
that the base form of Putina is Putin, as -a is the typi-
cal accusative ending of masculine names. Since the
subcategorization lexicon is not available, such in-
stances are either not covered or different heuristics
are employed for guessing the base form.

Additionally, grammar rules may produce vari-
ants of recognized full person names. For exam-
ple, for the full name CEO dr Jan Kowalski the fol-
lowing variants can be produced: Kowalski, CEO
Kowalski, dr Kowalski, etc. As the grammar rules
always return the longest match, a shorter form may
not be recognized. The produced variants are there-
fore used in the second pass through the text in order
to identify ‘incomplete’ forms. As no morphological
generation is involved, only base forms can be iden-
tified in this way. The system evaluation indicates
that 23.8% of the recognized names were identified
by this partial coreference resolution mechanism.

An analysis of incorrectly recognized named en-
tities (NEs) revealed that major problems concerned
(a) classical ambiguities, such as a proper name
vs. a common word, and (b) person vs. organization
name, caused by a specific word order and a
structural ambiguity of phrases containing NEs. Let
us consider the following examples to illustrate the
problems.

(2) Dane Federalnego Urzędu Statystycznego
Data_nominativus federalis_organizatio
nominalis statistici_organizatio
‘Data of the federal office for statistics’

(3) prezesa Della
president_nominativus Dell_organizatio
nominalis
‘president of Dell’

(4) kanclerz Austriaków
chancellor_nominativus Austriaci_organizatio
nominalis
‘chancellor of the Austrians’

(5) ‘... powiadał prezesa spółki Kruk
... said president_nominativus company_organizatio
nominalis Kruk
‘... said the president of Kruk company / Kruk, the
president of the company’

The text fragment Dane Federalnego in (2) is rec-
ognized by the grammar as a person name since
Dane is a gazetteer entry for a foreign (English) first
name. Consequently, Federalnego Urzędu Statys-
tycznego could not be recognized as an organization
name. Potentially, heuristics solving such NE over-
lapping collisions could improve the precision. Sim-
ilar techniques have been applied to other languages.
In (3) and (4) the names Della ‘of Dell’ and Austri-
akiów ‘of Austrians’ were erroneously recognized as
surnames. The rule matching a token representing
a title followed by a capitalized word, adopted for
English person names, is less reliable for Polish due
to declension of proper names and lack of prepo-
sitions in genitive constructions. One solution to
this problem would involve matching Della and Aus-
triaków with their base forms (Dell and Austriaci,
resp.), which might appear in the immediate con-
text. In this way, the name type could be validated.
However, a corpus inspection revealed that quite fre-
quently no base form appears in the same document.
The last example, (5), illustrates another problem,
which is even harder to solve. The phrase prezesa
spółki Kruk is structurally ambiguous, i.e., it can be bracketed as [prezes \[spółki Kruk\]] or [[prezes spółki] Kruk]. Consequently, the name Kruk might either refer to a company name (‘...said the president of the Kruk company’) or to a person name (‘...said Kruk, the president of the company’). Inferring the proper interpretation might not be possible even if we consider the subcategorization frame of the verb powiedzieć ‘to say’.

3.2 Evaluation

For evaluation of recognition and lemmatization of person names, a set of 30 articles on various topics (politics, finance, sports, culture and science) has been randomly chosen from Rzeczpospolita (Weiss, 2007), a leading Polish newspaper. The total number of person name occurrences in this document set amounts to 858. Evaluation of recognition’s precision and recall yielded 88.6% and 82.6%, respectively. Precision of lemmatization of first names and surnames achieved 92.2% and 75.6%, respectively. For 12.4% of the recognized person names more than one output structure was returned. For instance, in case of the person name Marka Belki, the first name Marka is interpreted by the gazetteer either as an accusative form of the male name Marek or as a nominative form of a foreign female name Marka. In fact, 10% of the Polish first-name forms in our gazetteer are ambiguous with respect to gender. As for the last name Belki, it is a genitive form of the common Polish noun belka ‘beam’, so the base form can be obtained directly. Nevertheless, as inflection of proper names differs from that of common nouns, various combinations of the regular noun Belka and the special proper name form Belki are possible, which increases ambiguity of the identified form. All possible lemmatizations are as follows:

(6) Marek Belka (masc.),
    Marka Belka (fem.),
    Marek Belki (masc.),
    Marka Belki (fem.)

A good heuristics to reduce such ambiguous lemmatizations is to prioritize rules which refer to morphological information over those which rely solely on orthography and/or token types.

4 Application of String Distance Metrics for Lemmatization

Since knowledge-based lemmatization of Polish NEs is extremely hard, we also explored a possibility of using string distance metrics for matching inflected person names with their base forms (and their variants) in a collection of document, rather than within a single document. The rest of this section describes our experiments in using different string distance metrics for this task, inspired by the work presented in (Cohen et al., 2003) and (Christen, 2006).

The problem can be formally defined as follows. Let $A$, $B$ and $C$ be three sets of strings over some alphabet $\Sigma$, with $B \subseteq C$. Further, let $f : A \rightarrow B$ be a function representing a mapping of inflected forms ($A$) into their corresponding base forms ($B$). Given, $A$ and $C$ (the search space), the task is to construct an approximation of $f$, namely $\hat{f} : A \rightarrow C$. If $\hat{f}(a) = f(a)$ for $a \in A$, we say that $\hat{f}$ returns the correct answer for $a$; otherwise, $\hat{f}$ is said to return an incorrect answer. For another task, a multi-result experiment, we construct an approximation $f^* : A \rightarrow 2^C$, where $f^*$ returns the correct answer for $a$ if $f(a) \in f^*(a)$.

4.1 String distance metrics

In our experiments, we have explored mainly character-level string metrics\(^3\) applied by the database community for record linkage.

Our point of departure is the well-known Levenshtein edit distance metric specified as the minimum number of character-level operations (insertion, deletion or substitution) required for transforming one string into another (Levenshtein, 1965) and bag distance metric (Bartolini et al., 2002) which is a time-efficient approximation of the Levenshtein metric. Next, we have tested the Smith-Waterman (Smith and Waterman, 1981) metric, which is an extension of Levenshtein metric and allow a variable cost adjustment to edit operations and an alphabet mapping to costs.

Another group of string metrics we explored is based on a comparison of character-level $n$-grams in two strings. The $q$-gram metric (Ukkonen, 1992) is

\(^3\)Distance (similarity) metrics map a pair of strings $s$ and $t$ to a real number $r$, where a smaller (larger) value of $r$ indicates greater (lower) similarity.
computed by counting the number of $q$-grams contained in both strings. An extension to $q$-grams is to add positional information, and to match only common $q$-grams that occur at a specified distance from each other (positional $q$-grams) (Gravano et al., 2003). Finally, the skip-gram metric (Keskustalo et al., 2006) is based on the idea that in addition to forming bigrams of adjacent characters, bigrams that skip characters are considered as well. Gram classes are defined that specify what kind of skip-grams are created, e.g. \{0, 1\} class means that regular bigrams (0 characters skipped) and bigrams that skip one character are formed. We have explored \{0, 1\}, \{0, 2\} and \{0, 1, 2\} gram classes.

Taking into account the Polish declension paradigm, we also added a basic metric based on the longest common prefix, calculated as follows:

$$CP_\delta(s,t) = ((|lcp(s,t)| + \delta)^2 / (|s| \cdot |t|)),$$

where $lcp(s,t)$ denotes the longest common prefix for $s$ and $t$. The symbol $\delta$ is a parameter for favoring certain suffix pairs in $s$ ($t$). We have experimented with two variants: $CP_{\delta_1}$ with $\delta = 0$ and $CP_{\delta_2}$, where $\delta$ is set to 1 if $s$ ends in: o, y, a, e, and $t$ ends in an a, or 0 otherwise. The latter setting results from empirical study of the data and the declension paradigm.

For coping with multi-token strings, we tested a similar metric called longest common substrings (LCS) (Christen, 2006), which recursively finds and removes the longest common substring in the two strings compared, up to a specified minimum length. Its value is calculated as the ratio of the sum of all found longest common substrings to the length of the longer string. We extended LCS by additional weighting the lengths of the longest common substrings. The main idea is to penalize the longest common substrings which do not match the beginning of a token in at least one of the compared strings. In such cases, the weight for $lcs(s,t)$ (the longest common substring for $s$ and $t$) is computed as follows. Let $\alpha$ denote the maximum number of non-whitespace characters which precede the first occurrence of $lcs(s,t)$ in $s$ or $t$. Then, $lcs(s,t)$ is assigned the weight:

$$w_{lcs(s,t)} = \frac{|lcs(s,t)| + \alpha - \max(\alpha, p)}{|lcs(s,t)| + \alpha}$$

where $p$ has been experimentally set to 4. We refer to the ‘weighted’ variant of LCS as W LCS.

Good results for name-matching tasks (Cohen et al., 2003) have been reported using the Jaro metric and its variant, the Jaro-Winkler (JW) metric (Winkler, 1999). These metrics are based on the number and order of common characters in two compared strings. We have extended the Jaro-Winkler metric to improve the comparison of multi-token strings. We call this modification JWM and it can be briefly characterized as follows. Let $J(s,t)$ denote the value of the Jaro metric for $s$ and $t$. Then, let $s = s_1 \ldots s_K$ and $t = t_1 \ldots t_L$, where $s_i (t_i)$ represent $i$-th token of $s$ and $t$ respectively, and assume, without loss of generality, $L \leq K$. JWM($s,t$) is defined as:

$$JWM(s,t) = J(s,t) + \delta \cdot boost_p(s,t) \cdot (1 - J(s,t))$$

where $\delta$ denotes the common prefix adjustment factor and $boost_p$ is calculated as follows:

$$boost_p(s,t) = \frac{1}{L} \cdot \sum_{i=1}^{L-1} \min(|lcp(s_i,t_i)|, p) + \frac{\sum_{i=1}^{L-1} \min(|lcp(s_i,t_i)|, p)}{L}$$

The main idea behind JWM is to boost the Jaro similarity for strings with the highest number of agreeing initial characters in the corresponding tokens in the compared strings.

Finally, for multi-token strings, we tested a recursive matching pattern, known also as Monge-Elkan distance (Monge and Elkan, 1996). The intuition behind this measure is the assumption that a token in $s$ (strings are treated as sequences of tokens) corresponds to a token in $t$ which has the highest number of agreeing characters. The similarity between $s$ and $t$ is the mean of these maximum scores. Two further metrics for multi-token strings were investigated, namely Sorted-Tokens and Permutted-Tokens. The first one is computed in two steps: (a) first, tokens forming a full string are sorted alphabetically, and then (b) an arbitrary metric is applied to compute the similarity for the ‘sorted’ strings. The latter compares all possible permutations of tokens forming the full strings and returns the calculated maximal similarity value.

A detailed description of string metrics used here is given in (Christen, 2006) and in (Piskorski et al., 2007).
4.2 Test Data
For the experiments on coreference of person names, we used two resources: (a) a lexicon of the most frequent Polish first names (PL-F(IRST)-NAMES) consisting of pairs of an inflected form and the corresponding base form, and (b) an analogous lexicon of inflected full person names (first name + surname) (PL-FULL-NAMES). The latter resource was created semi-automatically as follows. We have automatically extracted a list of 22485 full person-name candidates from a corpus of 15724 on-line news articles from Rzeczpospolita by using PL-F-NAMES lexicon and an additional list of 30000 uninfllected foreign first names. Subsequently, we have randomly selected a subset of about 1900 entries (inflected forms) from this list. In basic experiments, we simply used the base forms as the search space. Moreover, we produced variants of PL-F-NAMES and PL-FULL-NAMES by adding to the search space base forms of foreign first names and a complete list of full names extracted from the Rzeczpospolita corpus, respectively. Table 3 gives an overview of our test datasets.

| Dataset          | #inflected | #base | search space |
|------------------|------------|-------|--------------|
| PL-F-NAMES       | 3941       | 1457  | 1457         |
| PL-F-NAMES-2     | 3941       | 1457  | 25490        |
| PL-FULL-NAMES    | 1900       | 1219  | 1219         |
| PL-FULL-NAMES-2  | 1900       | 1219  | 2351         |
| PL-FULL-NAMES-3  | 1900       | 1219  | 20000        |

Table 3: Dataset used for the experiments

4.3 Evaluation Metrics
Since for a given string more than one answer can be returned, we measured the accuracy in three ways. First, we calculated the accuracy on the assumption that a multi-result answer is incorrect and we defined all-answer accuracy (AA) measure which penalizes multi-result answers. Second, we measured the accuracy of single-result answers (single-result accuracy (SR)) disregarding the multi-result answers. Finally, we used a weaker measure which treats a multi-result answer as correct if one of the results in the answer set is correct (relaxed-all-answer accuracy (RAA)).

Let \( s \) denote the number of strings for which a single result (base form) was returned. Analogously, \( m \) is the number of strings for which more than one result was returned. Let \( s_c \) and \( m_c \) denote, respectively, the number of correct single-result answers returned and the number of multi-result answers containing at least one correct result. The accuracy metrics are computed as: \( AA = s_c/(s + m) \), \( SR = s_c/s \), and \( RAA = (s_c + m_c)/(s + m) \).

4.4 Experiments
We started our experiments with the PL-F-NAME dataset and applied all but the multi-token strings distance metrics. The results of the accuracy evaluation are given in Table 4. The first three columns give the accuracy figures, whereas the column labeled AV gives an average number of results returned in the answer set.

| Metrics         | AA     | SR   | RAA   | AV    |
|-----------------|--------|------|-------|-------|
| Bag Distance    | 0.476  | 0.841| 0.876 | 3.02  |
| Levenshtein     | 0.708  | 0.971| 0.976 | 2.08  |
| Smith-Waterman  | 0.625  | 0.767| 0.795 | 2.07  |
| Jaro            | 0.775  | 0.820| 0.826 | 2.06  |
| Jaro-Winkler    | 0.820  | 0.831| 0.831 | 2.03  |
| q grams         | 0.714  | 0.974| 0.981 | 2.09  |
| post q grams    | 0.721  | 0.916| 0.982 | 2.09  |
| Skip grams      | 0.873  | 0.935| 0.956 | 2.14  |
| LCS             | 0.696  | 0.971| 0.977 | 12.69 |
| WLCS            | 0.731  | 0.983| 0.986 | 2.97  |
| \( CP_{\delta_2} \) | 0.829  | 0.843| 0.844 | 2.11  |
| \( CP_{\delta_s} \) | 0.947  | 0.956| 0.955 | 2.18  |

Table 4: Results for PL-F-NAMES

Interestingly, the simple linguistically-aware common prefix-based measure turned out to work best in the AA category, which is the most relevant one, whereas WLCS metrics is the most accurate in case of single-result answers and the RAA category. Thus, a combination of the two seems to be a reasonable solution to further improve the performance (i.e., if WLCS provides a single answer, return this answer, otherwise return the answer of \( CP_{\delta_2} \)). Next, the time-efficient skip grams metrics performed surprisingly well in the AA category. This result was achieved with \{ 0, 2 \} gram classes. Recall that about 10% of the inflected first name forms in Polish are ambiguous, as they are either a male or a female person name, see sec. 2.

Clearly, the AA accuracy figures in the experiment run on the PL-F-NAME-2 (with a large search space) was significantly worse. However, the SR
accuracy for some of the metrics is still acceptable. The top ranking metrics with respect to SR and AA accuracy are given in Table 5. Metrics which return more than 5 answers on average were excluded from this list. Also in the case of PL-F-NAME-2 the combination of WLC.S and CPδσ seems to be the best choice.

| Metrics          | SR     | AA     |
|------------------|--------|--------|
| WLC.S            | 0.893  | 0.469  |
| CPδσ₂            | 0.879  | 0.855  |
| pos 2-grams      | 0.875  | 0.457  |
| skip grams       | 0.852  | 0.567  |
| 2-grams          | 0.810  | 0.398  |
| LCS              | 0.768  | 0.340  |
| CPδσ₃₁           | 0.868  | 0.600  |
| JW               | 0.820  | 0.560  |

Table 5: Top results for PL-F-NAME-2

Finally, we have made experiments for full person names, each represented as two tokens. It is important to note that the order of the first name and the surname in some of the entities in our test datasets is swapped. This inaccuracy is introduced by full names where the surname may also function as a first name. Nevertheless, the results of the experiment on PL-FULL-NAMES given in Table 6 are nearly optimal. JWM, WLC.S, LCS, skip grams and Smith-Waterman were among the ‘best’ metrics.

| Internal Metrics | AA     | SR     | RAA    | AV    |
|------------------|--------|--------|--------|-------|
| Bag Distance     | 0.891  | 0.966  | 0.966  | 3.13  |
| Smith-Waterman   | 0.965  | 0.980  | 0.975  | 3.5   |
| Levenshtein      | 0.951  | 0.978  | 0.970  | 4.59  |
| Jaro             | 0.957  | 0.970  | 0.964  | 4.54  |
| JW               | 0.952  | 0.964  | 0.958  | 3.74  |
| JWM              | 0.962  | 0.974  | 0.968  | 3.74  |
| pos 2-grams      | 0.957  | 0.988  | 0.987  | 3.915 |
| pos 3-grams      | 0.953  | 0.994  | 0.996  | 4.32  |
| skip grams       | 0.973  | 0.991  | 0.990  | 5.14  |
| LCS              | 0.971  | 0.992  | 0.990  | 5.7   |
| WLC.S            | 0.975  | 0.993  | 0.992  | 6.29  |

Table 6: Results for PL-FULL-NAMES

The Monge-Elkan, Sorted-Tokens and Permutated-Tokens scored in general only slightly better than the basic metrics. The best results oscillating around 0.97, 0.99, and 0.99 for the three accuracy metrics were obtained using LCS, WLC.S, JWM and CPδ metrics as internal metrics. The highest score was achieved by applying Sorted-Tokens with JWM with 0.976 in AA accuracy.

Further, in order to get a better picture, we have compared the performance of the aforementioned ‘recursive’ metrics on PL-FULL-NAMES-2, which has a larger search space. The most significant results for the AA accuracy are given in Table 7. The JWM metric seems to be the best choice as an internal metric, whereas WLC.S, CPδσ and Jaro perform slightly worse.

| Internal Metrics | AA     | SR     | RAA    | AV    |
|------------------|--------|--------|--------|-------|
| Bag Distance     | 0.868  | 0.745  | 0.745  |       |
| Monge-Elkan      | 0.974  | 0.961  | 0.968  |       |
| Sorted-Tokens    | 0.976  | 0.975  | 0.975  |       |
| Permutated-Tokens| 0.976  | 0.976  | 0.976  |       |

Table 7: AA accuracy for PL-FULL-NAMES-2

In our last experiment we selected the ‘best’ metrics so far and tested them against PL-FULL-NAMES-3 (largest search space). The top results for non-recursive metrics are given in Table 8. JWM and WLC.S turned out to achieve the best scores.

| Metrics          | AA     | SR     | RAA    | AV    |
|------------------|--------|--------|--------|-------|
| Levenshtein      | 0.791  | 0.896  | 0.897  | 2.20  |
| Smith-Waterman   | 0.809  | 0.892  | 0.889  | 2.35  |
| JWM              | 0.791  | 0.807  | 0.802  | 2.11  |
| LCS              | 0.892  | 0.900  | 0.901  | 2.11  |
| skip grams       | 0.852  | 0.906  | 0.912  | 2.04  |
| WLC.S            | 0.827  | 0.925  | 0.930  | 2.48  |

Table 8: Results for PL-FULL-NAMES-3

The top scores achieved for the recursive metrics on PL-FULL-NAMES-3 were somewhat better. In particular, Monge-Elkan performed best with CPδσ (0.937 AA and 0.946 SR) and slightly worse results were obtained with JWM. Sorted-Tokens scored best in AA and SR accuracy with JWM (0.904) and WLC.S (0.949), respectively. Finally, for Permutated-Tokens the identical setting yielded the best results, namely 0.912 and 0.948, respectively.

5 Conclusions and Perspectives

For Slavic languages, rich and idiosyncratic inflection of proper names presents a serious problem for lemmatization. In this paper we investigated two different techniques for finding base forms of person names in Polish. The first one employs heuris-
tics and linguistic knowledge. This method does not provide optimal results at the moment as necessary tools and linguistic resources, e.g., a morphological generator or a subcategorization lexicon, are still underdeveloped for Polish. Moreover, contextual heuristics do not always find a solution as the required information might not be present in a single document. Therefore, we considered string distance metrics as an alternative approach. The results of applying various measures indicate that for first names, simple common prefix (CP₈) metric obtains the best results for all-answer accuracy, whereas the weighted longest common substrings (W LCS) measure provides the best score for the single-answer accuracy. Hence, a combination of these two metrics seems the most appropriate knowledge-poor technique for lemmatizing Polish first names. As for full names, our two modifications (W LCS and JWM) of standard distance metrics and CP₈ obtain good results as internal metrics for recursive measures and as stand-alone measures.

Although the results are encouraging, the presented work should not be considered a final solution. We plan to experiment with the best scoring metrics (e.g., for AA and SR) in order to find optimal figures. Additionally, we consider combining the two techniques. For example, string distance metrics can be used for validation of names found in the context. We also envisage applying the same methods to other types of proper names as well as to lemmatization of specialized terminology.

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