Abstract
This paper discusses several issues in Arabic orthography that were encountered in the process of performing morphology analysis and POS tagging of 542,543 Arabic words in three newswire corpora at the LDC during 2002-2004, by means of the Buckwalter Arabic Morphological Analyzer. The most important issues involved variation in the orthography of Modern Standard Arabic that called for specific changes to the Analyzer algorithm, and also a more rigorous definition of typographic errors. Some orthographic anomalies had a direct impact on word tokenization, which in turn affected the morphology analysis and assignment of POS tags.

1 Introduction
In 2002 the LDC began using output from the Buckwalter Arabic Morphological Analyzer (Buckwalter, 2002), in order to perform morphological annotation and POS tagging of Arabic newswire text. From 2002 to 2004 three corpora were analyzed and over half a million Arabic word tokens were annotated and tagged (see Table 1).

| Corpus  | Arabic Word Tokens |
|---------|--------------------|
| AFP     | 123,810            |
| Ummah   | 125,698            |
| Annahar | 293,035            |
| Total   | 542,543            |

Table 1: Arabic newswire corpora

The author was responsible for developing and maintaining the Analyzer, which primarily involved filling in the gaps in the lexicon and modifying the POS tag set in order to meet the requirements of treebanking efforts that were performed subsequently at the LDC with the same annotated and POS-tagged newswire data.

2 Lessons from the AFP corpus
During the tagging of the AFP data, the first corpus in the series, the Buckwalter Analyzer was equipped to handle basic orthographic variation that often goes unnoticed because it is a common feature of written Arabic (Buckwalter, 1992). This orthographic variation involves the writing (or omission) of hamza above or below alif in stem-initial position, and to a lesser extent, the writing (or omission) of madda on alif, also in stem-initial position. In both cases use of the bare alif without hamza or madda is quite common and goes by unnoticed by most readers. What took the LDC morphology annotation team by surprise was to find that in the AFP data the common omission of hamza in this environment had been extended to stem-medial and stem-final positions as well, as seen in the following words from that corpus: يدأت تأثير تأثير تأثير تأثير تأثير تأثير.

This type of orthographic variation was not attested to the same extent in the two subsequent corpora, Ummah and Annahar, which leads us to conclude that some orthographic practices might be restricted to specific news agencies. It is important to note that most of the native Arabic speakers who annotated the AFP data using the output from the Analyzer did not regard these omissions of hamza on alif in stem-medial and stem-final positions as orthographic errors, and fully expected the Analyzer to provide a solution.

3 Lessons from the Ummah corpus
During the tagging of the Ummah data, a different set of orthographic issues arose. Although the Buckwalter Analyzer was equipped to handle so-called “Egyptian” spelling (where word-final ya’ is spelled without the two dots, making it...
identical to \textit{alif maqṣura}, the Ummah corpus presented the LDC annotation team with just the opposite phenomenon: dozens of word-final \textit{alif maqṣura}’s spelled with two dots.\footnote{It is not entirely clear whether these “dotted” \textit{alif maqṣura}’s were produced by human typists or by an encoding conversion process gone awry. It is possible that the original keyboarding was done on a platform where word-final \textit{ya}’ and \textit{alif maqṣura} are displayed via visually identical “un-dotted” glyphs, so it makes no difference which of the two keys the typist presses on the keyboard: both produce the same visual display, but are stored electronically as two different characters.} Whereas some of the affected words were automatically rejected as typographical errors (e.g., 
\textit{الي الاعلي معي مني} which \textit{is} \textit{qala ‘anna} in Arabic, others where gladly analyzed at face value (e.g., 
\textit{ألذي علي} \textit{علني} \textit{الذي}). Unfortunately, this led to numerous false positive analyses: for example \textit{يالإني} was analyzed as ‘\textit{‘alī} and ‘\textit{‘alayya}, but not as ‘\textit{‘ala}. Initially, these words were tagged as typographical errors, but their pervasiveness led the LDC team to reconsider this position, upon which the author was asked to modify the Analyzer algorithm in order to accommodate this typographic anomaly. As a result, all words ending in \textit{ya}’ were now re-interpreted as ending in either \textit{ya}’ or \textit{alif maqṣura}, and both forms were analyzed, as seen in the following (abridged) output:\footnote{A key to the transliteration scheme used by the Analyzer can be found at \texttt{http://www.ldc.upenn.edu/myl/morph/buckwalter.html}}

\begin{verbatim}
<token_Arabic>لامي</token_Arabic>
<variant>Ely
<solution>
  <lemmaID>EalaY_1</lemmaID>
  <pos>Ealay/PREP+y/PRON_1S</pos>
  <gloss>on/above + ne</gloss>
</solution>
</variant>
</token_Arabic>

4 Lessons from all three corpora

The Annahar corpus presented no orthographic surprises, or at least nothing that the LDC annotation team had not seen before. The Annahar data did contain some additional orthographic features that we now identify as being common to all three corpora, as well as corpora outside the set we have annotated at the LDC.

The first orthographic feature relates to the somewhat free interchange of stem-initial \textit{hamza} above \textit{alif} and \textit{hamza} below \textit{alif}. With some lexical items the orthographic variation simply reflects variation in pronunciation: for example, both ‘\textit{isbaniya} (with \textit{hamza} under \textit{alif}) and ‘\textit{‘asbaniya} (with \textit{hamza} above \textit{alif}) are well attested. But in cases involving other orthographic pairs, more interpretations are possible. Take, for instance, what we called the “\textit{qala ‘anna}” problem. This problem was identified after numerous encounters with constructions in which \textit{qala} was followed by \textit{‘anna} rather than \textit{‘imma}, and for no apparent linguistic reason. Initially this was treated as a typographical error, but again, its pervasiveness forced us to take a different approach.

One solution we considered was to modify the Analyzer algorithm so that instances of stem-initial \textit{hamza} on \textit{alif} would also be treated as possible instances of \textit{hamza} under \textit{alif}, very much in the spirit of the approach we used for dealing with the \textit{alif maqṣura} / \textit{ya}’ free variation cited earlier. However, there is compelling evidence that the orthography of \textit{hamza} in stem-initial position is a fairly reliable indication of the perceived value of subsequent short vowel: \textit{a} or \textit{u} for \textit{hamza} above \textit{alif}, and \textit{i} for \textit{hamza} below \textit{alif}. In other words, there is no free variation. The decision was taken to regard “\textit{qala ‘anna}” constructions as grammatically acceptable in MSA.\footnote{Badawi, Carter and Gully regard “\textit{qala ‘anna}” constructions as grammatical but restricted to contexts “where the exact words of the speaker are not used or reported” (Badawi, Carter and Gully 2004, p. 713). This assertion could be investigated in the LDC corpora.}
Proper name phrases, especially those involving the word ‘abd (عبد) are also written either separately or in concatenated form. Part of the data annotation process at the LDC involves assigning case endings to tokenized words, but there is currently no mechanism in the Analyzer to assign two case endings (or several pairs of POS tags) to what is being processed as a single word token. As a result of this, the phrase ‘abd allah is assigned a single POS tag and case ending when it is written in concatenated form, but two POS tags and two case endings when written with intervening space.

The problem of assigning more than one case ending and POS tag to concatenations is more obvious in fully lexicalized concatenations such as khamsumi’atin, sittumi’atin, sab’umi’atin, etc (ساتما – ساتما – ساتما). When these numbers are written with intervening space (ساتما – ساتما – ساتما), two case endings and two POS tags are assigned by the Analyzer. But when they are written in concatenated form only one case ending and POS tag is assigned, and the “infixed” case ending of the first token is left undefined: khamsmi’atin, sittmi’atin, sab’mi’atin, etc.

So far we have discussed relatively controlled concatenation, involving mostly high-frequency function words and lexicalized phrases. But concatenation extends beyond that to random combinations of words—the only requirement being that the word immediately preceding end with a non-connector letter. These concatenations are fairly frequent, as attested by their Google scores (see Table 2).

It is important to note that these concatenations are not immediately obvious to readers due to the characteristics of proportionally spaced Arabic fonts. Most of the native readers of Arabic at the LDC did not consider concatenations such as these to be typographical errors. Their logic was best expressed in the statement: “I can read the text just fine. Why can’t the Morphological Analyzer?”

| Concatenation | Google Frequency |
|--------------|-----------------|
| مدير عام     | 846             |
| وزير الخارجية| 719             |
| مليار دولار | 162             |
| الدكتور محمد| 158             |
| عضومجلس     | 138             |
| وقتنم       | 130             |
| وانشاالي     | 99              |
| كمام         | 77              |
| عدكبير       | 54              |

Table 2: Arabic Concatenations and their Google Frequencies (sample taken March 25, 2004)

6 Conclusion

There are several levels of orthographic variation in Arabic, and each level calls for a specific response to resolve the orthographic anomaly. It is important that the output analysis record which method was used to resolve the anomaly. The methods used for resolving orthographic anomaly range from exact matching of the surface orthography to various strategies of orthography manipulation. Each manipulation strategy carries with it certain assumptions about the text, and these assumptions should be part of the output analysis. For example, an analysis of search obtained by exact matching in a text known to contain suspicious word-final ya’s (that may be alif maqṣūra’s) does not have the same value as an analysis of the same word, using the same exact matching, but in a text where word-final ya’s and alif maqṣūra’s display normal character distribution frequencies.

The problem of run-on words in Arabic calls for a reassessment of current tokenization strategies, including the definition of “word token” itself. It should be assumed that each input string represents one or more potential word tokens, each of which needs to be submitted individually for morphology analysis. For example, the input string قدتم can be segmented as a single word token, yielding two morphological analyses (faqad-tum and fa-qad-tum) or it can be segmented as two word tokens (fqd tm), yielding several possible analysis pairs (faqada / faqida / faqd / fa-qad + tamma).

5 We regard these as “fully lexicalized” concatenations because the first of the two constituent tokens ends in a connector letter. In other word, their concatenation is deliberate and not an accident of orthography.

6 By “tokenization” we mean the identification of orthographically valid character string units that can be submitted to the Analyzer for analysis. The Analyzer itself performs a different kind of “tokenization” by identifying prefixes and suffixes that are bound morphemes but which may be treated as “word tokens” in syntactic analysis.
Syntactic analysis would be needed for determining which morphology analysis is most likely the correct one for each tokenization (fqdtm and fqdtm).

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