# Towards Featureless Event Coreference Resolution via Conjoined Convolutional Networks

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## Abstract

Coreference resolution systems for entities and/or events almost invariably make use of many linguistic, parsing-based features which concern both the mention words (i.e., the entities and/or events) and their contexts. In contrast, we (1) introduce a new state-of-the-art event coreference resolution system which uses only lemmatization and its corresponding precomputed word-/char- embeddings; and (2) exhaustively illustrate the performance of other commonly-used features. The crux of our system is that it first makes pairwise event-coreference predictions by using a Siamese Convolutional Neural Network (henceforth referred to as Conjoined Convolutional Neural Network or CCNN). Next, we cluster the event mentions with a simple, but novel, neural approach which performs merges in an easy-first, cluster-holistic manner, allowing our system to be less susceptible to errors that are made from exclusively min-pairwise decision.

## 1 Introduction

Coreference resolution is the task of trying to identify – within a single text or across multiple documents – which *mentions* refer to the same underlying discourse *entity* or *event*. Naturally, one may be solely interesting in determining if two given entities co-refer to the same object (e.g., a pairwise prediction of *she* and *Mary* co-referring); however, ultimately, coreference resolution is a clustering task, whereby we wish to group all like-mentions together. Successfully doing so can be useful for several other core NLP tasks that concern natural language understanding, such as information extraction (Humphreys et al., 1997), topic detection (Allan et al., 1998), text summarization (Daniel et al., 2003), knowledge base population (Mayfield and et al., 2009), question answering (Narayanan and Harabagiu, 2004), etc. Coreference Resolution has always been one of the fundamental tasks within NLP, and with the ever-increasing amount of textual, digital data that is generated and consumed in present-day, it remains both important and challenging.

Specifically, coreference systems aim to find a globally-optimal fit of mentions to clusters, whereby every mention $m$ in the corpus is assigned to exactly one cluster $C$, the membership of which constitutes that every $m_i, m_j \in C_k$ is co-referent with each other. If a given $m_i$ is not anaphoric with any other $m_j$, then it should belong to its own $C_k$ with a membership of one. Further, the number of distinct clusters is not known apriori but is bounded by the number of mentions and is part of the system's inference. Finding such a globally-optimal assignment is NP-Hard and thus computationally intractable. In attempt to avoid this, systems typically perform pairwise-mention predictions, then use those predictions to build up clusters. The specific modelling strategies for such approximately fall into two categories: (1) mention-ranking / mention-pairs; and (2) entity-centric.

**Mention-ranking** models define a scoring a function $f(m_i, m_j)$ which operates on any $m_j$ and possible antecedent $m_i$, where $m_i$ occurs earlier in the document and could be null (represented by $\epsilon$ and denoting that $m_j$ is non-anaphoric). Although these models are by definition less expressive than entity-based models, their inference can be relatively simple and effective, allowing them to be fast and scalable. As a consequence, they have often been the approach used by many state-of-the-art systems (Soon et al., 2001; Durrett and Klein, 2013; Wiseman et al., 2016).

**Mention-pair** models are defined almost identically, with the subtle difference being the target objective of the pairwise-candidates. That is, mention-ranking model aim to find the ideal $m_i$ antecedent for every $m_j$, whereas mention-pair

models score all possible $(m_i, m_j)$ pairs (Bengtson and Roth, 2008).

**Entity-centric** models differ in that they focus on building a global representation of each underlying entity, the basis of which determines each mention's membership – as opposed to the most local pairwise- elements that comprise the aforementioned models.(Wiseman et al., 2016; Clark and Manning, 2016)

In this work, we use a novel and powerfully simple mention-ranking model that is designed solely to discriminate between input pairs of features: Siamese Convolutional Neural Networks, which, for political reasons, we will henceforth refer to as our newly-coined term, Conjoined Convolutional Neural Networks (or CCNN). Further, we aim to replace the main weakness of mention-ranking models with an approach resembling the main strength of entity-centric models. Specifically, we aim to combine all linked mention pairs into a cluster via a simple neural, easy-first, clustering approach which factors in a small, but effective, notion of the entire cluster at large.

Additionally, regardless of the modelling approach, most research typically uses a plethora of relatively-expensive parsing-based features, including dependency parse information, lemmatization, WordNet hypernyms/synonyms, FrameNet semantic roles, part-of-speech, etc. Although some research includes a listing of the learned feature weights of a system (corresponding to each feature's importance) (Yang et al., 2015), there has been a striking lack of work which takes the minimalistic approach and illustrates the effects of using few features. We aim to address this by starting with the widely-accepted strong baseline of *SameLemma* – two objects are co-referent if, and only if, they have the same lemmatization – and then evaluate the effectiveness of slowly adding other commonly used features.

Finally, in general, entity coreference resolution has received drastically more attention than event coreference. This lack of research could in part be due to events' often involving more complex nature: a single underlying event may be described via multiple lexicographically-differing mentions, yet different underlying events may also be represented by mentions that lexicographically look the same. This latter case is less common in entity coreference; other than pronouns, usually mentions' having the same text is a strong indication that the mentions are co-referent. In this paper, we are exclusively interested in event coreference.

In summary, we introduce a novel approach to event coreference resolution by performing mention-ranking with a Conjoined Convolutional Neural Network and unusually few features. We contribute a detailed performance analysis of other commonly used features. And last, we combine our predicted mention pairs into a cluster via a simple, neural approach which attempts to represent each cluster as a whole, yielding us with state-of-the-art results on the ECB+ corpus.

## 2 Related Work

## 3 General Instructions

Manuscripts must be in two-column format. Exceptions to the two-column format include the title, authors' names and complete addresses, which must be centered at the top of the first page, and any full-width figures or tables (see the guidelines in Subsection 3.6). **Type single-spaced.** Start all pages directly under the top margin. See the guidelines later regarding formatting the first page. The manuscript should be printed single-sided and its length should not exceed the maximum page limit described in Section 5. Pages are numbered for initial submission. However, **do not number the pages in the camera-ready version**.

By uncommenting `\aclfinalcopy` at the top of this document, it will compile to produce an example of the camera-ready formatting; by leaving it commented out, the document will be anonymized for initial submission. When you first create your submission on softconf, please fill in your submitted paper ID where `***` appears in the `\def\aclpaperid{***}` definition at the top.

The review process is double-blind, so do not include any author information (names, addresses) when submitting a paper for review. However, you should maintain space for names and addresses so that they will fit in the final (accepted) version. The NAACL-HLT 2018 LaTeX style will create a titlebox space of 2.5in for you when `\aclfinalcopy` is commented out.

The author list for submissions should include all (and only) individuals who made substantial contributions to the work presented. Each author listed on a submission to NAACL-HLT 2018 will be notified of submissions, revisions and the final decision. No authors may be added to or removed

from submissions to NAACL-HLT 2018 after the submission deadline.

### 3.1 The Ruler

The NAACL-HLT 2018 style defines a printed ruler which should be presented in the version submitted for review. The ruler is provided in order that reviewers may comment on particular lines in the paper without circumlocution. If you are preparing a document without the provided style files, please arrange for an equivalent ruler to appear on the final output pages. The presence or absence of the ruler should not change the appearance of any other content on the page. The camera ready copy should not contain a ruler. (LaTeX users may uncomment the `\aclfinalcopy` command in the document preamble.)

Reviewers: note that the ruler measurements do not align well with lines in the paper – this turns out to be very difficult to do well when the paper contains many figures and equations, and, when done, looks ugly. In most cases one would expect that the approximate location will be adequate, although you can also use fractional references (*e.g.*, the first paragraph on this page ends at mark 108.5).

### 3.2 Electronically-available resources

NAACL-HLT provides this description in LaTeX2e (`naaclhlt2018.tex`) and PDF format (`naaclhlt2018.pdf`), along with the LaTeX2e style file used to format it (`naaclhlt2018.sty`) and an ACL bibliography style (`acl_natbib.bst`) and example bibliography (`naaclhlt2018.bib`). These files are all available at `http://naacl2018.org/downloads/naaclhlt2018-latex.zip`. We strongly recommend the use of these style files, which have been appropriately tailored for the NAACL-HLT 2018 proceedings.

### 3.3 Format of Electronic Manuscript

For the production of the electronic manuscript you must use Adobe's Portable Document Format (PDF). PDF files are usually produced from LaTeX using the *pdflatex* command. If your version of LaTeX produces Postscript files, you can convert these into PDF using *ps2pdf* or *dvipdf*. On Windows, you can also use Adobe Distiller to generate PDF.

Please make sure that your PDF file includes all the necessary fonts (especially tree diagrams, symbols, and fonts with Asian characters). When you print or create the PDF file, there is usually an option in your printer setup to include none, all or just non-standard fonts. Please make sure that you select the option of including ALL the fonts. **Before sending it, test your PDF by printing it from a computer different from the one where it was created.** Moreover, some word processors may generate very large PDF files, where each page is rendered as an image. Such images may reproduce poorly. In this case, try alternative ways to obtain the PDF. One way on some systems is to install a driver for a postscript printer, send your document to the printer specifying "Output to a file", then convert the file to PDF.

It is of utmost importance to specify the **A4 format** (21 cm x 29.7 cm) when formatting the paper. When working with `dvips`, for instance, one should specify `-t a4`. Or using the command `\special{papersize=210mm,297mm}` in the latex preamble (directly below the `\usepackage` commands). Then using `dvipdf` and/or `pdflatex` which would make it easier for some.

Print-outs of the PDF file on A4 paper should be identical to the hardcopy version. If you cannot meet the above requirements about the production of your electronic submission, please contact the publication chairs as soon as possible.

### 3.4 Layout

Format manuscripts two columns to a page, in the manner these instructions are formatted. The exact dimensions for a page on A4 paper are:

- Left and right margins: 2.5 cm
- Top margin: 2.5 cm
- Bottom margin: 2.5 cm
- Column width: 7.7 cm
- Column height: 24.7 cm
- Gap between columns: 0.6 cm

Papers should not be submitted on any other paper size. If you cannot meet the above requirements about the production of your electronic submission, please contact the publication chairs above as soon as possible.

| Type of Text | Font Size | Style |
|---|---|---|
| paper title | 15 pt | bold |
| author names | 12 pt | bold |
| author affiliation | 12 pt | |
| the word "Abstract" | 12 pt | bold |
| section titles | 12 pt | bold |
| document text | 11 pt | |
| captions | 10 pt | |
| abstract text | 10 pt | |
| bibliography | 10 pt | |
| footnotes | 9 pt | |

Table 1: Font guide.

### 3.5 Fonts

For reasons of uniformity, Adobe's **Times Roman** font should be used. In LaTeX2e this is accomplished by putting

```
\usepackage{times}
\usepackage{latexsym}
```

in the preamble. If Times Roman is unavailable, use **Computer Modern Roman** (LaTeX2e's default). Note that the latter is about 10% less dense than Adobe's Times Roman font.

### 3.6 The First Page

Center the title, author's name(s) and affiliation(s) across both columns. Do not use footnotes for affiliations. Do not include the paper ID number assigned during the submission process. Use the two-column format only when you begin the abstract.

**Title**: Place the title centered at the top of the first page, in a 15-point bold font. (For a complete guide to font sizes and styles, see Table 1) Long titles should be typed on two lines without a blank line intervening. Approximately, put the title at 2.5 cm from the top of the page, followed by a blank line, then the author's names(s), and the affiliation on the following line. Do not use only initials for given names (middle initials are allowed). Do not format surnames in all capitals (*e.g.*, use "Mitchell" not "MITCHELL"). Do not format title and section headings in all capitals as well except for proper names (such as "BLEU") that are conventionally in all capitals. The affiliation should contain the author's complete address, and if possible, an electronic mail address. Start the body of the first page 7.5 cm from the top of the page.

| Command | Output |
|---|---|
| {\"a} | ä |
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| Command | Output |
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| {\c c} | ç |
| {\u g} | ğ |
| {\l} | ł |
| {\~n} | ñ |
| {\H o} | ő |
| {\v r} | ř |
| {\ss} | ß |

Table 2: Example commands for accented characters, to be used in, *e.g.*, BibTeX names.

The title, author names and addresses should be completely identical to those entered to the electronical paper submission website in order to maintain the consistency of author information among all publications of the conference. If they are different, the publication chairs may resolve the difference without consulting with you; so it is in your own interest to double-check that the information is consistent.

**Abstract**: Type the abstract at the beginning of the first column. The width of the abstract text should be smaller than the width of the columns for the text in the body of the paper by about 0.6 cm on each side. Center the word **Abstract** in a 12 point bold font above the body of the abstract. The abstract should be a concise summary of the general thesis and conclusions of the paper. It should be no longer than 200 words. The abstract text should be in 10 point font.

**Text**: Begin typing the main body of the text immediately after the abstract, observing the two-column format as shown in

the present document. Do not include page numbers.

**Indent**: Indent when starting a new paragraph, about 0.4 cm. Use 11 points for text and subsection headings, 12 points for section headings and 15 points for the title.

### 3.7 Sections

**Headings**: Type and label section and subsection headings in the style shown on the present document. Use numbered sections (Arabic numerals) in order to facilitate cross references. Number subsections with the section number and the subsection number separated by a dot, in Arabic numerals. Do not number subsubsections.

**Citations**: Citations within the text appear in parentheses as (Gusfield, 1997) or, if the author's name appears in the text itself, as Gusfield (1997). Using the provided LaTeX style, the former is accomplished using `\cite` and the latter

| output | natbib | previous ACL style files |
|---|---|---|
| (Gusfield, 1997) | `\citep` | `\cite` |
| Gusfield (1997) | `\citet` | `\newcite` |
| (1997) | `\citeyearpar` | `\shortcite` |

Table 3: Citation commands supported by the style file. The citation style is based on the natbib package and supports all natbib citation commands. It also supports commands defined in previous ACL style files for compatibility.

with `\shortcite` or `\newcite`. Collapse multiple citations as in (Gusfield, 1997; Aho and Ullman, 1972); this is accomplished with the provided style using commas within the `\cite` command, *e.g.*, `\cite{Gusfield:97,Aho:72}`. Append lowercase letters to the year in cases of ambiguities. Treat double authors as in (Aho and Ullman, 1972), but write as in (Chandra et al., 1981) when more than two authors are involved. Collapse multiple citations as in (Gusfield, 1997; Aho and Ullman, 1972). Also refrain from using full citations as sentence constituents.

We suggest that instead of

> "(Gusfield, 1997) showed that ..."

you use

> "Gusfield (1997) showed that ..."

If you are using the provided LaTeX and BibTeX style files, you can use the command `\citet` (cite in text) to get "author (year)" citations.

If the BibTeX file contains DOI fields, the paper title in the references section will appear as a hyperlink to the DOI, using the hyperref LaTeX package. To disable the hyperref package, load the style file with the `nohyperref` option:
`\usepackage[nohyperref]{naaclhlt2018}`

**Digital Object Identifiers**: As part of our work to make ACL materials more widely used and cited outside of our discipline, ACL has registered as a CrossRef member, as a registrant of Digital Object Identifiers (DOIs), the standard for registering permanent URNs for referencing scholarly materials. As of 2017, we are requiring all camera-ready references to contain the appropriate DOIs (or as a second resort, the hyperlinked ACL Anthology Identifier) to all cited works. Thus, please ensure that you use BibTeX records that contain DOI or URLs for any of the ACL materials that you reference. Appropriate records should be found for most materials in the current ACL Anthology at `http://aclanthology.info/`.

As examples, we cite (Goodman et al., 2016) to show you how papers with a DOI will appear in the bibliography. We cite (Harper, 2014) to show how papers without a DOI but with an ACL Anthology Identifier will appear in the bibliography.

As reviewing will be double-blind, the submitted version of the papers should not include the authors' names and affiliations. Furthermore, self-references that reveal the author's identity, *e.g.*,

> "We previously showed (Gusfield, 1997) ..."

should be avoided. Instead, use citations such as

> "Gusfield (1997) previously showed ... "

Any preliminary non-archival versions of submitted papers should be listed in the submission form but not in the review version of the paper. NAACL-HLT 2018 reviewers are generally aware that authors may present preliminary versions of their work in other venues, but will not be provided the list of previous presentations from the submission form.

**Please do not use anonymous citations** and do not include when submitting your papers. Papers that do not conform to these requirements may be rejected without review.

**References**: Gather the full set of references together under the heading **References**; place the section before any Appendices, unless they contain references. Arrange the references alphabetically by first author, rather than by order of occurrence in the text. Provide as complete a citation as possible, using a consistent format, such as the one for *Computational Linguistics* or the one in the *Publication Manual of the American Psychological Association* (American Psychological Association, 1983). Use of full names for authors rather than initials is preferred. A list of abbreviations for common computer science journals can be found in the ACM *Computing Reviews* (for Computing Machinery, 1983).

The LaTeX and BibTeX style files provided roughly fit the American Psychological Association format, allowing regular citations, short citations and multiple citations as described above.

Submissions should accurately reference prior and related work, including code and data. If a piece of prior work appeared in multiple venues, the version that appeared in a refereed, archival venue should be referenced. If multiple versions of a piece of prior work exist, the one used by the authors should be referenced. Authors should not rely on automated citation indices to provide accurate references for prior and related work.

**Appendices**: Appendices, if any, directly follow the text and the references (but see above). Letter them in sequence and provide an informative title: **Appendix A. Title of Appendix**.

### 3.8 Footnotes

**Footnotes**: Put footnotes at the bottom of the page and use 9 point font. They may be numbered or referred to by asterisks or other symbols.[1] Footnotes should be separated from the text by a line.[2]

### 3.9 Graphics

**Illustrations**: Place figures, tables, and photographs in the paper near where they are first discussed, rather than at the end, if possible. Wide illustrations may run across both columns. Color illustrations are discouraged, unless you have verified that they will be understandable when printed in black ink.

**Captions**: Provide a caption for every illustration; number each one sequentially in the form: "Figure 1. Caption of the Figure." "Table 1. Caption of the Table." Type the captions of the figures and tables below the body, using 11 point text.

### 3.10 Accessibility

In an effort to accommodate people who are colorblind (as well as those printing to paper), grayscale readability for all accepted papers will be encouraged. Color is not forbidden, but authors should ensure that tables and figures do not rely solely on color to convey critical distinctions. A simple criterion: All curves and points in your figures should be clearly distinguishable without color.

[1]This is how a footnote should appear.

[2]Note the line separating the footnotes from the text.

## 4 Translation of non-English Terms

It is also advised to supplement non-English characters and terms with appropriate transliterations and/or translations since not all readers understand all such characters and terms. Inline transliteration or translation can be represented in the order of: original-form transliteration "translation".

## 5 Length of Submission

The NAACL-HLT 2018 main conference accepts submissions of long papers and short papers. Long papers may consist of up to eight (8) pages of content plus unlimited pages for references. Upon acceptance, final versions of long papers will be given one additional page – up to nine (9) pages of content plus unlimited pages for references – so that reviewers' comments can be taken into account. Short papers may consist of up to four (4) pages of content, plus unlimited pages for references. Upon acceptance, short papers will be given five (5) pages in the proceedings and unlimited pages for references.

For both long and short papers, all illustrations and tables that are part of the main text must be accommodated within these page limits, observing the formatting instructions given in the present document. Supplementary material in the form of appendices does not count towards the page limit; see appendix A for further information.

However, note that supplementary material should be supplementary (rather than central) to the paper, and that reviewers may ignore supplementary material when reviewing the paper (see Appendix A). Papers that do not conform to the specified length and formatting requirements are subject to be rejected without review.

Workshop chairs may have different rules for allowed length and whether supplemental material is welcome. As always, the respective call for papers is the authoritative source.

## Acknowledgments

The acknowledgments should go immediately before the references. Do not number the acknowledgments section. Do not include this section when submitting your paper for review.

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## A Supplemental Material

Submissions may include resources (software and/or data) used in in the work and described in the paper. Papers that are submitted with accompanying software and/or data may receive additional credit toward the overall evaluation score, and the potential impact of the software and data will be taken into account when making the acceptance/rejection decisions. Any accompanying software and/or data should include licenses and documentation of research review as appropriate.

NAACL-HLT 2018 also encourages the submission of supplementary material to report preprocessing decisions, model parameters, and other details necessary for the replication of the experiments reported in the paper. Seemingly small preprocessing decisions can sometimes make a large difference in performance, so it is crucial to record such decisions to precisely characterize state-of-the-art methods.

Nonetheless, supplementary material should be supplementary (rather than central) to the paper. **Submissions that misuse the supplementary material may be rejected without review.** Essentially, supplementary material may include explanations or details of proofs or derivations that do not fit into the paper, lists of features or feature templates, sample inputs and outputs for a system, pseudo-code or source code, and data. (Source code and data should be separate uploads, rather than part of the paper).

The paper should not rely on the supplementary material: while the paper may refer to and cite the supplementary material and the supplementary material will be available to the reviewers, they will not be asked to review the supplementary material.

Appendices (*i.e.* supplementary material in the form of proofs, tables, or pseudo-code) should come after the references, as shown here. Use `\appendix` before any appendix section to switch the section numbering over to letters.

## B Multiple Appendices

. . . can be gotten by using more than one section. We hope you won't need that.