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AND PHYSICS**
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MASTER THESIS

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Entity Relationship Extraction

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In date
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Dedication.

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Introduction

This thesis researches relationship extraction in Czech. Relationship extraction is the task of extracting semantic relationship from a text. It is closely connected to named entity recognition, the task of tagging entities in text with their corresponding type, and entity linking, the task of disambiguating named entities to a knowledge base. If all those task are used together, we could gain knowledge databases automatically from text.

For English multiple attempts were made to solve or at least advance in relationship extraction, varying both in task assignment and in used technologies.

To be able to approach this set of tasks, we will focus on pure relationship extraction and thus the following restriction: we will only extract relations from sentences with labeled subject and object for the potential relation. We will benefit from the state-of-the-art technologies such as BERT from Devlin et al. [2018].

A key role in modern machine learning play datasets. In major part of this thesis, we will address the absence of a Czech dataset for relationship extraction. We will generate our dataset by aligning Wikidata¹ with Czech Wikipedia². This type of aligning is sometimes referred to as distant supervision. We will also need to recognize entities includes other . We will than be able to train different models and we will also be able to discuss how choices made in dataset generation affect the ability of a model to learn.

Given the absence of a dataset, we also deal with an absence of a baseline for model performance. To show that, at least the proposed architecture and training method we used, are comparable to state of the art result we will perform the same training with English BERT and we will evaluate it on some well known English datasets.

0.1 Thesis organization

This thesis is split in two parts. Before we dive into the first part, we will provide information that is relevant for this thesis, but is not part-specific, such as more details on relationship extraction, connected terminology and further motivation. We will briefly introduce the Czech language to explain why existing distant supervision methods were most likely not applied on Czech.

The first part will focus on datasets. We will present some existing supervised datasets, we will propose methodology for generating the dataset via distant supervision and elaborate on the process of implementation.

In the second part, we will finally talk about the modern technologies, we will try to pinpoint the important aspects of models, etc. we are using. We will use the Transformers³ library which makes training well-known pre-trained models accesible.

¹<https://www.wikidata.org/wiki/>

²<https://cs.wikipedia.org/wiki/>

³<https://github.com/huggingface/transformers/>

divná
věta

previous
work:
Ex-
isting
work on
relation
extrac-
tion
(e.g.,
Zelenko
et al.,
2003;
Mintz
et al.,
2009;
Adel
et al.,
2016)

which
meth-
ods,
were
they
not?

co víc
tam je

je tam
vizuali-
zovatko

whatever
prostě
to
nejdřív
udělej,
pak o
tom piš

1. Relationship extraction intro

změnit
název

1.1 Terminology

Terminology in NLP subtasks is often not exact or non-standardized. We will attempt to introduce following concepts as exactly as possible and respecting the terms that seem to be established by majority.

hloupá
věta

Relation in this context is semantic (not grammatical etc.). It has a type, is binary and oriented and describes relationship between a relation subject and a relation object.

Relation subject and **relation object**. Subject is the first argument of relation, object the second. In the sentence “Albus Severus is Harry Potters’s son.” a relation of type SON is captured, subject is John and object is Eric. The reasoning for this choice of direction is as follows: suppose we are gathering information about Harry, than we would probably have both the information that his son is Albus Severus and his father is James. So we are gathering information about the subject (Harry Potter), even though in most sentences like “James is Harry’s father.” Harry is a grammatical object. We will use the notation `RELATION TYPE(subject,object): SON(Harry Potter,Albus Severus Potter)`.

will we,
lepší
vzhled

Both subject and object can generally be any word or sequence of words that have the ability to form relations. In some cases subjects, objects or both are limited to entities or named entities.

Named entity is a real-world object, such as persons, locations, organizations, products, etc., that can be denoted with a proper name. It can be abstract or have a physical existence. Named entities can simply be viewed as entity instances (e.g., New York City is an instance of a city). Sometimes, numeric data is considered in this category as well (for example by NER tools).

ukradeno
z wiki,
ocitovat
nebo
ukráct
od
jinud

Relation inventory is the set of types of relations, that are considered valid for given dataset or model.

rozepsat
ner

Relation mention is a sentence, that captures a relation, together with type of the relation and tagged subject and object.

Negative mention is close to relation mention in the sense that it is a sentence with tagged subject and object, but the relation type is one of these types:

odrážky

- **OTHER** - human annotator would classify a relation of type, that is not in relation inventory.
- **NO RELATION** - in this case, human annotator should feel an absence of relation between subject and object.

doplnit
příklady,
včetně
vyložene
ne
příkladu

NO RELATION comes with difficulties. Since there is no semantic relation between subject and object, it makes it harder to choose subject-object pairs. It is probably desirable to have subject-object pairs, that could be related in a different sentence.

Relationship Extraction
Lemma

znímit
entity z
názvu

A form
from a
lexeme
chosen
by con-
vention
(e.g.,
nomi-
nati-

1.2 Czech language

One of the objective of this thesis is to work with Czech language, therefore we find it useful to make some notes on Czech (for non Czech speaking readers). Czech is a Slavic language with rich morphology and relatively free word order. Most of Czech morphology can be treated with a morphological analyzer, still, it might be useful to have a better understanding of the language we will work with.

1.2.1 Declanation

In Czech, nouns, adjectives, pronounce and numerals are inflected. The inflection expresses (not necessarily unambiguously) one of seven cases and a number (singular or plural). Any inflected word in Czech has a grammatical gender, for words, that have natural gender, those two genders align: “žena” (*woman*) is feminine and “muž” (*man*) is masculine. Inflection of each inflective word follows a pattern. This all means that a single word (lemma) can have a lexeme of size

Verbs are conjugated, the conjugation expresses person, numeral, tense, voice and mode. Verbs follow one of 14 patterns and average Czech either finds the theory about Czech verbs and tenses confusing, or is unaware there even are verb patterns. With that, we will not elaborate on conjugation.

An important aspect of declanation for us is agreement. In English, subject and verb agrees (limited just to third person). In Czech subject and verb also agree, but in noun phrases there needs to be an agreement as well.

An abstract entity; the set of all forms related by inflection (but not derivation).

příklad:
toho,
jak je
nějaká
noun
phrase,
počet
lexémů,
počet
validních
..

odkaz
dopředu,
kde
řeším,
jak
matchovat

2. Existing datasets

In this chapter, we will overview well-known datasets related to Entity Relationship Extraction. We will start with supervised datasets (SEMEVAL 2010 task 8 and TACRED), then we will focus on distant supervision.

tady
představíme
exis-
tující
datasty

2.1 SEMEVAL 2010 task 8 dataset

The SemEval-2010 Task 8 dataset (S10T8) was introduced in SemEval-2010 Task 8: Multi-Way Classification of Semantic Relations Between Pairs of Nominals Hendrickx et al. [2010]. We will summarize how S10T8 was created and some other information from that article so that later we can compare different approaches.

The authors started by choosing an inventory of semantic relations. They aimed for such a set of relations that it would be exhaustive (enable the description of relations between any pair of nominals) and mutually exclusive (given context and a pair of nominals only one relation should be selectable). Chosen relations with descriptions and examples are listed in table 2.1.

nějak
napsat,
že
nebudu
citovat,
ale
je to
hodně
vykradené?

They decided to accept as relation arguments any noun phrases with common-noun heads not just named entities or some other specific class of noun phrases, mentioning 'Named entities are a specific category of nominal expressions best dealt with using techniques which do not apply to common nouns.' But they restricted noun phrases to single words with the exception to lexicalized terms (such as science fiction).

proč
není
table
součást
od-
kazu?

nechat
ut tu
citaci?

quote
better

formát

The annotation process had three rounds. In the first round, authors manually collected around 1,200 sentences for each relation through pattern-based Web search (with at least a hundred patterns per relation). This way, they obtained around 1200 sentences for each relation. In the second round, each sentence was annotated by two independent annotators. In the third round disagreements were resolved and the dataset was finished. Every sentence was classified either as a true relation mention or was a near-miss and thus classified as "other", or was removed.

lepší
uvo-
zovky

The dataset contains of 10717 relation mentions. For the original competition, teams were given three training dataset of sizes 1000 (TD1), 2000 (TD2), 4000 (TD3), and 8000 (TD4). There was a notable gain TD3 → TD4 therefore the authors concluded that even larger dataset might be helpful to increase performance of models. But

.. that is so much easier said than done: it took the organizers well in excess of 1000 person-hours to pin down the problem, hone the guidelines and relation definitions, construct sufficient amounts of trustworthy training data, and run the task.

2.2 TACRED dataset

The TAC Relation Extraction Dataset was introduced in Zhang et al. [2017]. TACRED is a supervised dataset obtained via crowdsourcing. It contains about

Table 2.1: S10T8 summary. List of relations, their official descriptions, a random example and both relative and absolute count.

CAUSE-EFFECT	12.4%
An event or object leads to an effect.	(1331)
Example: <i>The <u>burst</u> has been caused by water hammer <u>pressure</u>.</i>	
INSTRUMENT-AGENCY	6.2%
An agent uses an instrument.	(660)
Example: <i>The <u>author</u> of a keygen uses a <u>disassembler</u> to look at the raw assembly code.</i>	
PRODUCT-PRODUCER	8.8%
A producer causes a product to exist.	(948)
Example: <i>The <u>factory</u>'s products have included flower pots, Finnish rooster-whistles, pans, <u>trays</u>, tea pots, ash trays and air moisturisers.</i>	
CONTENT-CONTAINER	6.8%
An object is physically stored in a delineated area of space.	(732)
Example: <i>This cut blue and white striped cotton <u>dress</u> with red bands on the bodice was in a <u>trunk</u> of vintage Barbie clothing.</i>	
ENTITY-ORIGIN	9.1%
An entity is coming or is derived from an origin (e.g., position or material).	(974)
Example: <i>The <u>avalanches</u> originated in an extensive <u>mass</u> of rock that had previously been hydrothermally altered in large part to clay.</i>	
ENTITY-DESTINATION	10.6%
An entity is moving towards a destination.	(1137)
Example: <i>This book has transported <u>readers</u> into <u>ancient times</u>.</i>	
COMPONENT-WHOLE	11.7%
An object is a component of a larger whole.	(1253)
Example: <i>The system as described above has its greatest application in an arrayed <u>configuration</u> of antenna <u>elements</u>.</i>	
MEMBER-COLLECTION	8.6%
A member forms a nonfunctional part of a collection	(923)
Example: <i>The <u>student association</u> is the voice of the undergraduate student population of the State University of New York at Buffalo.</i>	
MESSAGE-TOPIC	8.4%
A message, written or spoken, is about a topic.	(895)
Example: <i>Cieply's <u>story</u> makes a compelling <u>point</u> about modern-day studio economics.</i>	
OTHER	17.4%
	(1864)
Example: <i>The <u>child</u> was carefully wrapped and bound into the <u>cradle</u> by means of a cord.</i>	

100 000 examples.

The authors are relatively brief about the data collection process:

We create TACRED based on query entities and annotated system responses in the yearly TAC KBP evaluations. In each year of the TAC KBP evaluation (2009–2015), 100 entities (people or organizations) are given as queries, for which participating systems should find associated relations and object entities. We make use of Mechanical Turk to annotate each sentence in the source corpus that contains one of these query entities. For each sentence, we ask crowd workers to annotate both the subject and object entity spans and the relation types.

TACRED relation inventory captures only relations with subject being an organization or a person. Objects are of following types: cause of death, city, country, criminal charge, date, duration, ideology, location, misc (used for alternative name relation and no_relation only), nationality, number, organization, person, religion, state or province, title and url.

TACRED was designed to be highly unbalanced. 79.5% of data is the no_relation relation, which should be closer to real-world text and supposedly should help with not predicting false positive. However even if we look only at actual relations, there are vast differences in frequency: top six relations make up half the dataset and bottom six less than 2%. In absolute numbers the least common ord:dissolved relation has only 33 examples and median is only 286 examples.

Table 2.2: TACRED summary. List of relations, their official descriptions, a random example and both relative and absolute count.

NO_RELATION	79.5%
Example: “ <i>One step at a time</i> , ” said Con Edison spokesman Chris Olert in <i>Sunday editions of The Daily News</i> .	(84490)
ORG:ALTERNATE_NAMES	1.3%
Example: <i>The ARMM was established as a result of the peace agreement between the government and the <u>Moro National Liberation Front</u> -LRB- <u>MNLF</u> -RRB- in 1996 .</i>	(1358)
ORG:CITY_OF_HEADQUARTERS	0.5%
Example: <i>Once completed , the cuts will leave the <u>Irvine</u> , California-based <u>Option One</u> subsidiary with about 1,400 employees .</i>	(572)
ORG:COUNTRY_OF_HEADQUARTERS	0.7%
Example: <i>The Review based its report on a new survey conducted by the <u>International Agency for Research on Cancer</u> in <u>Lyon</u> , <u>France</u> .</i>	(752)
ORG:DISSOLVED	0.0%
Example: <i>News Corp. sold its satellite television service <u>DirecTV</u> in <u>2008</u> to <u>Liberty Media</u> .</i>	(32)
ORG:FOUNDED	0.2%
Example: <i>New York-based <u>Zirh</u> was founded in <u>1995</u> and makes products using natural oils and extracts .</i>	(165)
ORG:FOUNDED_BY	0.3%
Example: <i>The <u>Jerusalem Foundation</u> , a charity founded by <u>Kollek</u> 40 years ago , said he died of natural causes Tuesday morning .</i>	(267)

ORG:MEMBER_OF	0.2%
Example: <i>Lyons and the <u>Red Sox</u> say they are n't aware of any other <u>Major League Baseball</u> team with such an arrangement .</i>	(170)
ORG:MEMBERS	0.3%
Example: <i>The NFL refused to abandon the city , and the <u>Saints</u> won the <u>NFC South</u> in 2006 , their first season with Brees and Payton .</i>	(285)
ORG:NUMBER_OF_EMPLOYEES/MEMBERS	0.1%
Example: <i>Established in September 1969 , the <u>organization</u> now has <u>57</u> member states worldwide .</i>	(120)
ORG:PARENTS	0.4%
Example: <i>The initial offering of AIA raised \$ 178 billion for AIG , while the sale of <u>ALICO</u> to <u>MetLife</u> reaped about \$ 155 billion .</i>	(443)
ORG:POLITICAL/RELIGIOUS_AFFILIATION	0.1%
Example: <i>Manila signed a peace treaty with the <u>MNLF</u> in 1996 , ending a decades-old separatist campaign in return for limited <u>Muslim</u> self-rule .</i>	(124)
ORG:SHAREHOLDERS	0.1%
Example: <i>Stop the NAACP and <u>Al Sharpton</u> 's <u>National Action Network</u> from committing this disgrace in our community .</i>	(143)
ORG:STATEORPROVINCE_OF_HEADQUARTERS	0.3%
Example: <i>Learn More <u>Chelsea District Library</u> 221 S Main St Chelsea , <u>MI</u> 48118 -LRB- 734 -RRB- - 475-8732 Find it on a map</i>	(349)
ORG:SUBSIDIARIES	0.4%
Example: <i>The new law will also enable the government to take over <u>Austral Lineas Aereas</u> , an <u>Aerolineas Argentinas</u> subsidiary .</i>	(452)
ORG:TOP_MEMBERS/EMPLOYEES	2.6%
Example: <i>Earlier this year , <u>Anatoly Isaikin</u> , head of <u>Rosoboronexport</u> , said Russia still considers Iran a valuable arms customer .</i>	(2769)
ORG:WEBSITE	0.2%
Example: <i><u>Swiss Bankers Association</u> : http://www.swissbanking.org</i>	(222)
PER:AGE	0.8%
Example: <i>Doctor <u>Carolyn Goodman</u> , Rights Champion , Dies at <u>91</u></i>	(832)
PER:ALTERNATE_NAMES	0.1%
Example: <i><u>Remy Ma</u> , whose real name is <u>Remy Smith</u> , is charged with first - degree assault and other charges .</i>	(152)
PER:CAUSE_OF_DEATH	0.3%
Example: <i>The cause was <u>kidney failure</u> , said a spokesman for the <u>Ali Akbar College of Music</u> .</i>	(336)
PER:CHARGES	0.3%
Example: <i>Actor <u>Danny Glover</u> has been convicted in Canada for <u>trespassing</u> in a hotel during a union rally in 2006 .</i>	(279)
PER:CHILDREN	0.3%
Example: <i><u>Al-Hakim</u> 's son , <u>Ammar al-Hakim</u> , has been groomed for months to take his father 's place .</i>	(346)
PER:CITIES_OF_RESIDENCE	0.7%
Example: <i>As part of a Navy family , <u>she</u> also lived in Long Beach , Calif. , San Diego and <u>Annapolis</u> .</i>	(741)
PER:CITY_OF_BIRTH	0.1%
Example: <i><u>Jane Matilda Bolin</u> was born on April 11 , 1908 , in <u>Poughkeepsie</u> , NY .</i>	(102)
PER:CITY_OF_DEATH	0.2%
Example: <i>The statement was confirmed by publicist Maureen O'Connor , who said <u>Dio</u> died in <u>Los Angeles</u> .</i>	(226)

PER:COUNTRIES_OF_RESIDENCE	0.8%
Example: <i>His wife , who accompanied Yoadimnadjji to Paris , will repatriate his body to <u>Chad</u> , the ambassador said .</i>	(818)
PER:COUNTRY_OF_BIRTH	0.0%
Example: <i>CARACAS , Jan 10 -LRB- Xinhua -RRB- <u>Hugo Chavez</u> , was born on July 28 , 1954 , in <u>Venezuela</u> 's Sabaneta .</i>	(52)
PER:COUNTRY_OF_DEATH	0.1%
Example: <i>Egypt 's state-owned Middle East News Agency said <u>Tantawi</u> died in <u>Saudi Arabia</u> , where he attended a religious ceremony .</i>	(60)
PER:DATE_OF_BIRTH	0.1%
Example: <i>Antonioni was born in <u>1912</u> in the northern Italian city of <u>Ferrara</u> .</i>	(102)
PER:DATE_OF_DEATH	0.4%
Example: <i><u>December 6 , 2007</u> <u>Jefferson DeBlanc</u> , Hero Pilot , Dies at 86 By RICHARD GOLDSTEIN</i>	(393)
PER:EMPLOYEE_OF	2.0%
Example: <i><u>He</u> and his group also joined in a legal battle challenging the <u>Washington Redskins</u> ' trademarked name .</i>	(2162)
PER:ORIGIN	0.6%
Example: <i>French media are reporting that <u>French</u> tennis player <u>Mathieu Montcourt</u> had died at the age of 24 .</i>	(666)
PER:OTHER_FAMILY	0.3%
Example: <i>In the interview <u>Cunningham</u> acknowledged the fragility of <u>his</u> choreographic record .</i>	(318)
PER:PARENTS	0.3%
Example: <i>The outgoing governor of Barinas is <u>Hugo de los Reyes Chavez</u> , father of <u>Hugo</u> and Adan Chavez .</i>	(295)
PER:RELIGION	0.1%
Example: <i><u>He</u> closed out the quarter making seven payments to <u>Scientology</u> groups totaling \$ 13,500 .</i>	(152)
PER:SCHOOLS_ATTENDED	0.2%
Example: <i><u>She</u> graduated from <u>Mount Holyoke College</u> in 1941 and from the Yale School of Law in 1948 .</i>	(228)
PER:SIBLINGS	0.2%
Example: <i><u>Raul Castro</u> , <u>Fidel</u> 's younger brother , has made several overtures toward Washington .</i>	(249)
PER:SPOUSE	0.5%
Example: <i>After returning to Dothan in 1946 , <u>Flowers</u> married <u>Mary Catherine Russell</u> .</i>	(482)
PER:STATEORPROVINCE_OF_BIRTH	0.1%
Example: <i><u>Thomas Joseph Meskill Jr</u> was born in New Britain , <u>Conn</u> , on Jan 30 , 1928 .</i>	(71)
PER:STATEORPROVINCE_OF_DEATH	0.1%
Example: <i>Jessica Weiner says <u>Greenwich</u> died of a heart attack at St. Luke 's Roosevelt Hospital in <u>New York</u> .</i>	(103)
PER:STATEORPROVINCES_OF_RESIDENCE	0.5%
Example: <i>Sen. <u>Chris Dodd</u> of <u>Connecticut</u> has proposed taxing polluters for their carbon emissions .</i>	(483)
PER:TITLE	3.6%
Example: <i><u>He</u> is the founder and leader of Architects and Engineers for 9/11 Truth -LRB- AE911Truthorg -RRB- .</i>	(3861)

3. CERED

In this chapter we will describe the process of generating **Czech Relationship Extraction Dataset (CERED)**. We will discuss various decisions that were made during this process and their impacts. We will start by characterizing available data and technological resources.

a co dál

3.1 Czech Wikipedia and Wikidata

Wikipedia is a multilingual online encyclopedia created and maintained as an open collaboration project by a community of volunteers Wikipedia contributors [2020] and we believe anyone reading this article is familiar with Wikipedia. From our point of view Wikipedia is a corpus of text with tagged topics of articles and some entity mentions. Czech Wikipedia contains approximately 440 000 articles and ranks top 30 across all the different language editions of Wikipedia.¹

Wikidata is a knowledge base, which acts as central storage of the structured data of Wikipedia and other Wikimedia projects. Just like Wikipedia, this project is freely available and edited by users (and bots). It provides the option to query the database online (for small enough queries), but it is also possible to download the database in standard formats.

The database focuses on **items**, which represent objects, entities, concepts, etc. The first data collected in Wikidata were links to multilingual version of Wikipedia articles on the same topic, the same Wikidata item. Each item was assigned an identifier, prefix Q and unique number, referred to as **QID**. A label together with a description of an item should serve as a human readable identifier. Labels, descriptions and optional aliases are language dependant.

Properties, another big concept of Wikidata, can be thought of as categories of items (mother *P25* implies a category of all mothers) or as relations between items (Ron Weasley *Q173998* has a mother *P25* Molly Weasley *Q3255012*). Each property has its **PID**, which is a identifier consisting of a prefix P and an unique number.

hezčí
formátování
wiki-
itemm

3.2 Title of the second subchapter of the second chapter

¹As of March 2020 according to https://en.wikipedia.org/wiki/List_of_Wikipedias

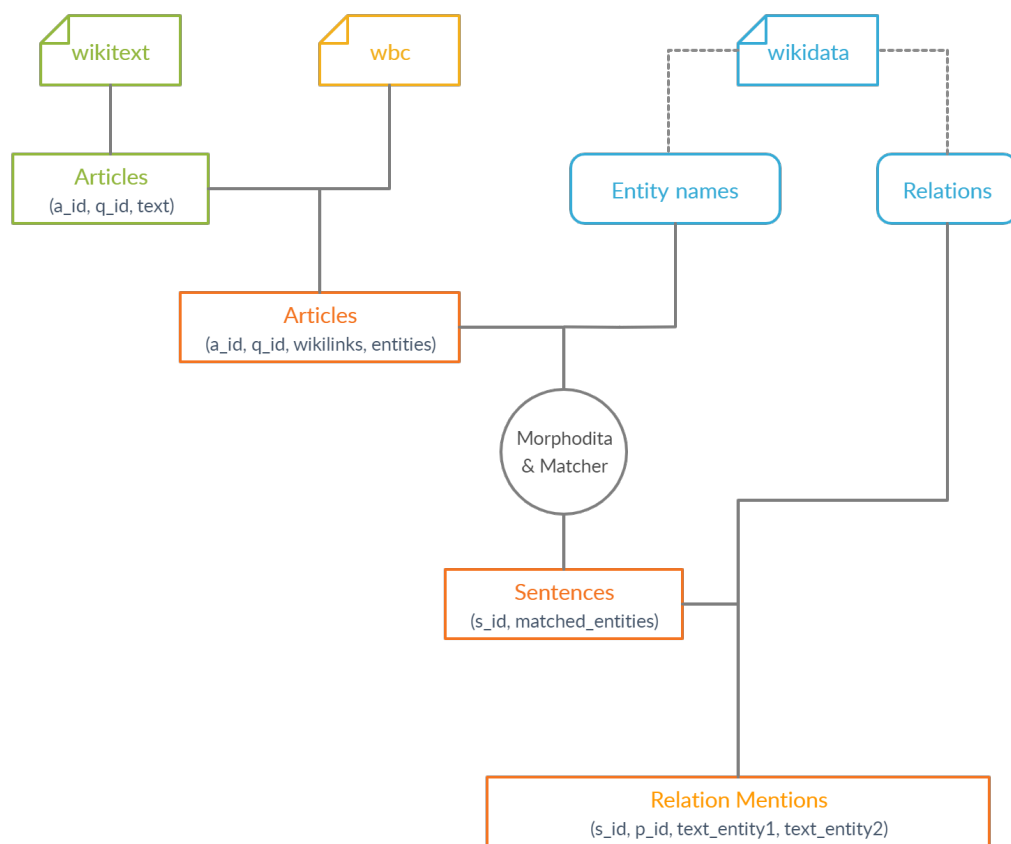


Figure 3.1: Zjednodušený diagram výroby korpusu

4. Existing ML věci

Conclusion

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A. Attachments

A.1 First Attachment