

Location Unaware Wayfinding

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ABSTRACT

A computational model of understanding place descriptions is a cardinal issue in multiple disciplines and provides critical applications especially in dialog-driven geolocation services. This research targets the automated extraction of spatial triplets to represent qualitative spatial relations between recognized places from natural language place descriptions via a simple class of locative expressions. We attempt to produce triplets, informative and *convenient* enough as a medium to convert verbal descriptions to graph representations of places and their relationships. We present a reasoning approach devoid of any external resources (such as maps, path geometries or robotic vision) for understanding place descriptions. We then apply our methodologies to situated place descriptions and study the results, its errors and implied future research.

Categories and Subject Descriptors

H.3.1 [Information Storage and Retrieval]: content analysis and indexing - *Linguistic processing*; I.2.7 [Artificial Intelligence]: Natural Language Processing - *Language parsing and understanding*

General Terms

Experimentation, algorithms, languages, performance

Keywords

Place descriptions, spatial role labelling, spatial language understanding, locative expressions, triplets

1. INTRODUCTION

Human wayfinding is the process of purposeful and directed movement from an origin to a specific destination. The problem of wayfinding is the identification of the ordered sequence of actions to be performed in a spatial environment to reach at a desired location. In our everyday interaction with the spatial environment, we are involved with

different instances of wayfinding tasks. In some, the exact sequence of actions is well familiar but in others we need either an external assistance or a personal strategy to find our ways. The modern advancements in technology have diminished the efforts involved in discovering and implementing wayfinding strategies. With the advent of smartphones, it has been made possible to build powerful applications which can show maps, compute routes and determine current location via GPS positioning. It has removed the complexities of carrying a map and understanding its symbols and notations. Significant efforts have been put into the research and development of the systems for navigational assistance using smartphones.

Despite the powerful services offered as digital navigational aids, there come several issues along with it. Apart from the installation and usage costs associated with these services, the accuracy behind the positioning systems is a vital concern. The inaccuracies extend from measurement errors in positioning algorithms from the satellites to the map matching algorithms at the application end. The situation becomes worse when the navigation route goes through narrow streets under tall buildings. Since the services rely upon the details in the map and the crowdsourced information available, the success in utility is highly variable.

In addition to the above shortcomings in modern digital navigation aids, research works have identified user preference for auditory presentation for route information as well as a memory advantage for auditory over visual information. Experiments have indicated that the reaction times are fastest with pure auditory route instructions as compared to electronic route maps or turn-by-turn displays.

These findings motivated us to work on a system which exploits the auditory mode of route guidance, eliminates the use of global positioning systems and works on minimum map information.

There have been several measures executed and advancements accomplished to decrease the accuracies.

A place description provides spatial information in terms of spatial features and the spatial relations between them. Place descriptions are used in everyday activities in spatial learning, problem solving and decision support in large-scale environments, independent and typically in absence of access to a map or a compass. The task of mapping a two-dimensional environment into a linear structure of language descriptions can also take a dynamic nature where a human uses a tour route for communicating spatial information [19, 5]. Thus, place descriptions can also be thought of encompassing path descriptions. To add to the complex-

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ity, the descriptions can be situated in a specific context and thus use indirect references (*to its east, that building*). Also, the spatial features can be simple features (e.g., house, park) or place names (official or informal). Nonetheless, this challenging task of understanding the natural language place descriptions provides critical applications in numerous domains including instruction following robots, description based localization in query/dialog driven geolocation services such as navigation, emergency assistance, and automated geo-tagging of text. In addition, having inferred the spatial relations from such a description, the translation of the relatively abstract verbal descriptions to more iconic media of conveying information (e.g., pictures and sketch maps) becomes easier.

This research targets the automated extraction of spatial triplets to represent spatial features and relations between them from natural language place descriptions via a degenerate form of locative expressions. *Locative expressions* as described by Herskovits [8], are expressions containing a preposition, its object and whatever the prepositional phrase modifies (i.e., subject of preposition). We, however, start from a degenerate form of locative expressions that are devoid of a subject. We provide a detailed definition for such expressions in Section 3.1.2. The challenge of this paper is to extract the subject of these degenerate locative expressions to complete a spatial triplet.

The extraction process is accompanied with a trained learning model ([21]) which predicts the beginning and the span of a degenerate locative expression in a sentence using Conditional Random Fields (CRFs) along-with the place names indicators (gazetteers and manual annotations). It gives a good indication on the spatial relations in Natural Language (NL) text and can be used to extract triplets in the format of an object of interest, a reference object and a prepositional relation that connects the two. This representation is derived from the technique of Spatial Role Labelling (SpRL) [16], where the preposition serves as a spatial indicator connecting a trajectory (object of interest) with a landmark (reference object). The end goal of this effort is to ease the translation of verbal descriptions to graph representations (with features as nodes and relations as edges). The aim is to make the triplets as *informative* and *convenient* as possible for such a translation. By being *informative*, we mean to exploit the spatial information in the three components of the triplets. Also, the triplet output format becomes *convenient* enough to a translator if it cuts down the linguistic complexities.

The introduction of the problem leads to the fundamental question: Given a degenerate locative expression, is it possible to extract the spatial triplets without introducing any additional ambiguities? If yes, how effective is it to use degenerate locative expressions (DLEs) to identify the underlying spatial triplets. In this paper we present a technique to extract the triplets representing recognized objects or place names and spatial relationships between them with the help of DLEs. We claim our extracted triplets to be qualitative and informative enough to assist in sketch-map generation and graphical depictions. However for the purpose of extraction of triplets, we target only the *static triplets* which don't demand interpretation of spatial motion. We then investigate the different types of errors in the results of triplet extraction and highlight the gaps in the approach of its inability to resolve the indirect reference in a descrip-

tion and end by pointing out the challenges for dealing with full-blown English place descriptions.

2. RELEVANT WORK

We are interested in the extraction of geographic information in the form of triplets, from unrestricted NL place descriptions. Research in the past had focused on mining specific and application-dependent geographic information from controlled language expressions [10, 18, 24] or from certain contexts, such as route descriptions. Hornsby and Li [9] provided a conceptual framework that could serve as the basis for the tagging and parsing of text to extract movement information, while the semantics of locative expressions of various languages are studied in Kracht et al. [17]. Linguistic constructs are often complex and lead to under or over-specifications when trying to match NL to formal frameworks of spatial information. As argued in [4], most computational aspects of geographic information do not consider these linguistic intricacies, especially in the construction of formal models of spatial relations based on the logic of human spatial cognition. The authors also argue that such formal models do not acknowledge the way that people actually express spatial relations linguistically. Therefore, Bateman [3] suggests a semantics and linguistics based spatial ontology that would facilitate better mappings between spatial calculi and NL spatial expressions, such as the Generalized Upper Model ontology (GUM) [2].

In more recent works, researchers have been working on parsers that can process unrestricted language input, and thus, come closer to the parser discussed in this paper. For example, Zlatev [28] worked on the cognitive linguistic research in spatial semantics and provided basic theoretical concepts for understanding it, in the form of the holistic spatial semantic theory. Based on that theory, Kordkamshidi et al. [15] then implemented spatial role labeling (SpRL), a method with which they assigned reference objects, locata and spatial relations roles to linguistic terms. This technique facilitates mapping the terms onto formal spatial relations and is also used in this work. The authors suggest machine learning techniques to deal with ambiguity in linguistic spatial information and in [16], they utilize the proposition project (TPP) from SemEval-2007 [20] for disambiguating the spatial meanings of prepositions and enhancing the SpRL technique. Zlatev [28] worked on the cognitive linguistic research in spatial semantics and provided basic theoretical concepts for understanding it. Ever since then, there has been growing trend to understand natural language (NL) descriptions. The research has moved towards understanding unrestricted NL in current works ([16, 22, 13]). The methodology suggested in this paper makes use of no external resources (such as maps, vision), but employs a machine learning tool [21] to identify place names and the associated prepositional phrases. Hereafter, we work with the concept and reasoning approach to form rules for extracting useful spatial information from the text.

3. THEORY

3.1 Definitions

In this section, comprehensive definitions of the major terms that appear in this paper, viz spatial triplets (or simply triplets) and degenerate locative expressions (DLE), are

provided.

3.1.1 Spatial Triplets

A spatial triplet is a triple of a locatum (*LOC*), reference object (*RO*) and a spatial relation (*r*). Here, RO is the object by which the location of the LOC is defined, using the prepositional relation *r*. For example, `< Melbourne Hospital diagonally across Peter Doherty Institute >` references *Melbourne Hospital* as the LOC in terms of *Peter Doherty Institute* as RO by the relation *diagonally across* as *r*. Vasardani et al. [26] provide more information on the theory and the structure of triplets. This method of defining spatial relation is derived from the technique of Spatial Role Labelling (SpRL), which first appeared in [16], and which was also conceptually verified in Kracht et al. [17] for many languages, as the *configuration* and *mode* layers of locative expressions. In SpRL, one assigns spatial role labels to the words or phrases in sentences from the set {*trajector* (tr), *spatial Indicator* (si), *landmark* (l)}. For example, such a labelled sentence looks like: “[*We*]_{tr} are sitting [*in*]_{si} [*the Baretto’s*]_l [*in*]_{si} [*the Alan Gilbert Building*]_l”. However, spatial triplets that could be extracted out of such a sentence look like :

`<We in the Baretto’s>`

`<We in the Alan Gilbert Building>`

Arguably, a spatial triplet relation provides a more convenient representation of spatial information than the role labels, and provides a suitable medium to translate the verbal description to a graph representation.

3.1.2 Degenerate Locative Expressions (DLE)

A locative expression is a spatial referring expression which contains a preposition, its object, and whatever the prepositional phrase modifies (i.e., subject of preposition) [8]. These expressions have been adopted as a standard for spatial semantics and cognition and are widely referred to [23, 28]. However, in informal communication or a situated dialog, people tend to disregard the subject and describe the location in terms of just the preposition and its object (e.g., [I am] at Deakin University). We term such locative expressions as degenerate locative expressions (DLE). In a crowd-sourced corpus of place descriptions [1] people described their location mostly in terms of DLEs (e.g., *at the University of Melbourne, in my house*). Hence, an attempt was made to identify the DLEs and train a model on this available dataset to provide predictions on any test corpus.

Classification of Degenerate Locative Expressions

From the definition of a degenerate locative expression (DLE), one can think of constructions like “of the train-station”, “from the University” and “to Bourke Street”. Such examples do follow from the definition but cannot convey any spatial relationship independently. Binary spatial relationships are not informative when naively using non-locative prepositions (e.g., X *from* Y is not an informative relationship). Such DLEs require special treatment before the corresponding triplet relation could be extracted. We term such DLEs as *partial DLEs*. These expressions include all those spatial expressions which do not start with locative prepositions¹. The rest of the DLEs, which start with a preposition of location and thus give a sense of spatial relation are termed as

¹*at, in* and *on* are treated as locative prepositions, the rest of the prepositions are treated as non-locative.

locative DLEs. For example, *in the alley* is a locative DLE. The procedures for triplet extraction described in the subsequent sections are described first for locative DLEs and then for partial DLEs.

3.2 Extracting Spatial Triplets

To deal with the task of spatial information extraction, we set ourselves the aim of identifying ‘informative’ triplets. The problem can be defined similarly to a spatial role labelling task (SpRL), the difference being that we attempt not to miss any information from the place names and the spatial relation. For an example from the SpRL dataset, “two men are standing on a lawn in front of a light brown house with blue corners”, SpRL marks one of the reference object as ‘house’ to eventually give the triplet `<lawn in front of house>`. However, we are interested in including any informative meaning inherent in the description and thus output “lawn in front of light brown house”. This also becomes essential in the long term goal of translating verbal descriptions to graphical depictions, where the graph/sketch drawing algorithm could be vitally benefitted by localizing the spatial feature to ‘light brown house’ rather than just any ‘house’ (from the above example). There have been various datasets used for identifying spatial expressions [2, 7, 14] but none are characteristic enough of a place description. For instance, place descriptions are more descriptive than mere spatial expressions and the spatial relations can be fairly complex and difficult to formalise (e.g., ‘between’, ‘across from’). Due to the goals set thereafter and the fact that there is no available dataset for training on such special and essential requirements, a reasoning approach, rather than a machine-learning approach is chosen here for extracting triplet relations. This approach helps in understanding place descriptions and thus eventually aiding machine learners by revealing the structure and identifying relevant/irrelevant attributes.

The task of triplet extraction poses varying challenges owing to the complex nature of place descriptions. The spatial relations can be defined either simply using position descriptors (e.g., on, at, in) or using concepts of motion and indirect references [28]. For example, in “From here, you can go left towards X and then head north to reach Y”, the phrase “from here” carries context (indirect reference) and the current context is shown spatially related to X and Y via motion indicators. For the purpose of this paper we limit ourselves from the detection of spatial motion and resolution of indirect references and instead focus on the structure of static place-descriptions. The triplet extraction assumes all descriptions are static, i.e., without any context or motion. This process of extraction of triplets goes through the DLEs by categorising them into the two types: *locative* and *partial*. We start by describing the process of triplet extraction for locative DLEs, and then move forward to deal with partial DLEs.

Locative DLEs

Given the DLEs, to identify the triplets, one needs to find the subject of DLE. For example, in “There is a construction site in the alley”, the DLE is ‘in the alley’ and the triplet extracted should be `<construction site in the alley>`. To identify the subject, the dependency between the preposition *in* and the two noun places ‘construction site’ and ‘the alley’ need to be identified. Luckily, from the Stanford

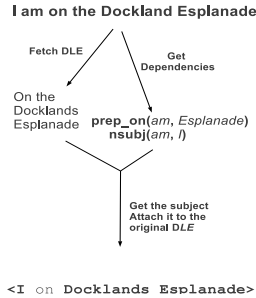


Figure 1: Sample run of the identification process for locative DLE in the sentence “I am on the Docklands Esplanade”

typed dependencies parser [6] one can extract the dependencies between the words of a sentence. Using the collapsed dependencies representation, *prep* relation reports a prepositional phrase and the verb/noun/adjective modified by the prepositional phrase. In the syntactic terminology of the Stanford dependency parser, the former is called the dependent and the latter is called the governor. In this case, the dependency reported is *prep_in*(site,alley) where ‘site’ is the governor and ‘alley’ is the dependent. When the relation is between two nouns, the triplet relation is direct. However, in the case of verb/adjective, we further explore the typed dependencies to find the subject or the noun modified by the corresponding verb/adjective. The subject finding task (for verb/adjective/noun) then recursively checks for the modifiers of the subject (if any) by searching through the set of modifier relations provided by typed dependencies. The final triplet is reported thereafter. The steps to extract triplets from a sample sentence for the case of *prep* relation involving a verb is shown in Figure 1.

In descriptions where a person describes a location using references to pronouns, e.g., *You can also find NAB and Commonwealth bank branches near the Union House*, the direct object of the verb gets linked to its prepositional relation (*near*). So, in this sentence, subject of the verb *find* is *You*, but the direct objects are *NAB* and *Commonwealth Bank*, and thus the triplet should be *<NAB near Union House>* (and not *You near Union House*). Thus, the heuristic that works here is: if there is a direct object of the verb, report the direct object as the locatum of the triplet. The heuristic can be further strengthened by using the fact that in such cases the nominal subject of the verb is a pronoun.

Partial DLEs

The partial DLEs convey no spatial information independently but they form a medium for inferring spatial relationships in the place description. As mentioned earlier, partial DLEs can be converted to locative DLEs in some sentences and can be directly used to output triplets. In other cases, a partial DLE can be made informative and meaningful by just extending its prepositional clause. For example, consider the sentence “I am 300 meters far from the auburn train-station” with the partial DLE “from the auburn train-station”. Clearly, by including the “300 meters far [from]” we get a more informative triplet *<I 300 meters far from the train station>*. Thus, the aim is to capture this infor-

mation from the typed dependencies. Table 1 provides the exhaustive rules to extract this information from the typed dependencies. By doing this, we exploit the locative purpose served by a partial DLE. Thereafter, we proceed similar to a locative DLE to find subject of the preposition.

4. IMPLEMENTATION

The methodology mentioned in the previous section works on the natural language via the results of a parser which is trained to identify degenerate locative expressions in informal text [21]. The parser trains a *conditional random field* (CRF) machine learning model on the manually annotated corpus of place descriptions [1] and attempts to identify both informal and formal place references. To enhance its prediction scores, it can exploit external resources such as gazetteers and dictionaries. The output provided by the parser is in the form of *in-out of-beginning* of (IOB) encoding. IOB encoding is used for extent-identification tasks in *Natural Language Processing* where each word is marked as either the beginning of an entity (B-NP), inside an entity (I-NP) or outside the entity (O). The entities in this case are the DLEs. The DLEs output by the parser are either simply place names (e.g., Chetwynd Place) or place names with prepositional attachments (e.g., of the train station).

The parser is written in *Python* and our program works on top of it. The input requirements for the parser are met by *Part-of-Speech* (POS) tagging and shallow parsing (*chunking*) the sentences. POS-tagging corresponds to determining the part-of-speech tag (e.g., noun, verb, adverb) associated with a word, whereas shallow parsing is the process of grouping words in a sentence as *chunks* to analyse the syntactic structures. Besides this, the parser can be aided in locating place references by marking the place names and manually annotating them with information such as granularity and identifiability. The format of these manual annotations follows the scheme provided by Tytyk and Baldwin [25]. The use of manual annotations or gazetteers is optional, but can be included to enhance the DLE prediction scores. For each DLE extracted from the parser, our program identifies its subject (after extending prepositional clauses for partial DLEs) using the output of the *Stanford parser* [12] for POS tags and dependencies in the original sentences. The program is tested on the *Tell Us Where* dataset [1] and a set of university campus descriptions.²

5. EXPERIMENTAL STUDY

In this section, the experimental analysis of our methodology is presented. First, the dataset used for testing out the methodology is described. Next, an insight to the performance of our approach for extracting triplets from our corpora, the *Tell Us Where* mobile game dataset and the set of campus descriptions, is given. The quantitative results are presented in Table-4 while the quality of the results is elaborated with the use of several examples from the test corpora. Finally, the errors produced in extracting the triplets and the sources behind them, as well as the types of triplets missed by the approach are discussed.

5.1 Dataset Description

²See Section 5.1 for description on the datasets.

Table 1: Extending the prepositional relations of direction using Stanford dependencies (DEP)

Governor	Action on relation	Example	
		Sentence	Actions
noun	extend with the noun and its modifiers	Its the 3rd house from the station.	DEP : prep_from (house, station) extends <i>from</i> to “3rd house from”
adjective	extend with the adjective	My house is next to the station.	DEP : prep_to (next, station) extends <i>to</i> to “next to”
verb	extend with the verb’s modifiers*	I am living 2 minutes from the station.	DEP : prep_from (living, station) adds modifiers of <i>living</i> (‘2 minutes’) extends <i>from</i> to “2 minutes from”

*-preference to verb’s direct object (if any)

For our experimental study, we used the *Tell Us Where* dataset [1] as one of the test corpora. The dataset comes from a location based mobile game which locates its users and asks them: “Tell us where you are”. Originally, the corpus consisted of 1,858 place descriptions but for the purpose of this research, descriptions containing fewer than 20 words are filtered out. This gives 54 distinct situated place descriptions, each of which describes relationships among two or more places. Additionally, a set of four NL descriptions of the Parkville campus of the University of Melbourne is parsed, none of which originally are less than 100 words. These were submitted by graduate students with varying degrees of familiarity with the campus. Also, there were no instructions given to the students while submitting the descriptions, which yields a set of unrestricted NL place descriptions. With such datasets, our testing model is set up to be descriptive enough, constraint-free and thus more natural in relation to, and characteristic of place descriptions.

5.2 Extraction Of Triplets

The task of extracting ‘spatially informative’ triplets from NL descriptions is challenging and cannot be directly dealt with a standard language parser. The DLE parser aids in separating the place names, and manual annotations to enhance the DLE parser are employed. Table-4 provides the extent of success in triplet extraction in terms of accuracy and recall on the corpus of campus descriptions. As indicated, usage of manual annotations has a positive effect on the success metrics but the magnitude of the differences is small enough to keep intact the aim of an eventual complete automation of triplets extraction. We now focus on the triplets extraction study pertaining to static place descriptions. The parser’s output in such cases has a fair similarity with the expected triplets. Below are some of the example cases representative of the results.

EXAMPLE 1. *I am [at a 3 stories town house], number 7 [Chetwynd Place]. [The house] is located [in a small alley] [behind a row of town house] [along Chetwynd Street], [near the corner] [between Chetwynd Street and Queensberry Street]. There is [a construction site] [in the alley]. Its the 3rd house from the head [of the alley].*

This example is taken from the *Tell Us Where* corpus. The bracketed texts correspond to the DLEs identified by the parser. The triplets output by the program are presented in Table 2. This is a characteristic example of a static place

description without any indirect reference, except in the last sentence where ‘it’ is used in place of “the house” and thus no triplet was extracted. If the sentence is rephrased as “*I am in the 3rd house from the head of the alley*”, the triplet extracted is, *<I in 3rd house from the head of the alley>*³. Not all triplets inherent in the description were extracted. Nonetheless, from the output of the parser, it can be seen that the triplets contain more information as compared to that in spatial role labels and yet stay simple enough to be interpretable to a graphical depiction algorithm. In the above examples, when one using spatial role modelling, the roles would not carry the information that the *town house* is *3 stories* or that the *alley* is *small*, nor that the construction site is small.

The next example, Example-2, indicates success of the approach on the extraction of triplets corresponding to a ternary relation like *between*. The ‘between’ relation is spatially informative, but not syntactically suitable for a triplet, as it has two reference objects connected to the same locatum. This inhibits the computational interpretation of triplets. Vasardani *et al.* [26] discuss the semantics of triplet relations, and propose that triples with ‘between’ can be broken into two, by identifying the conjuncts of the dependent (e.g., ‘building’ and ‘the campus’ in Example-2.).⁴

EXAMPLE 2. *Between this building and [the campus], [on Swanston St], is the major public transport hub for [the University].*

Triplets extracted:

<the major public transport hub between building>
<the major public transport hub between the campus>
<the major public transport hub on Swanston St>

EXAMPLE 3. *We’re sitting [in Baretto]’s [in the Alan Gilbert Building], [across Grattan street] is one of the [medical buildings]. [Down the hill] [along Grattan street] the [new building] being constructed is the [Peter Doherty Institute] and diagonally across the road ([Royal Parade]) is [Melbourne Hospital]. In the other direction the open area is*

³See how the preposition ‘from’ gets extended to ‘3rd house from’, and the clause related to the preposition ‘of’ gets attached into the reference object as ‘head of the alley’

⁴The conjuncts were not separately identified for *between* relation in Example-1 because of the presence of the connector ‘and’, which forces the DLE parser to identify *Chetwynd Street and Queensberry Street* as one single place name

<I at a 3 stories town house>
<The house in a small alley>
<a small alley behind a row of town house>
<The house along Chetwynd Street>
<The house near the corner>
<the corner between Chetwynd Street and Queensberry Street>
<a construction site in the alley>

Table 2: Parser output for triplet extraction in Example 1

<We in Baretto>
<We in Alan Gilbert Building>
<one of medical buildings across Grattan street>
<the Peter Doherty Institute Down the hill>
<the hill along Grattan street>
<the law building at the city end of University square>
<an entrance across Grattan street from University square>

Table 3: Program output for triplet extraction in Example 2

[University square] (there is a [carpark] underneath). At the city end [of University square] is [the law building]. [Across Grattan street] [from University square] there is [an entrance] [to the campus], straight ahead is [an overpass building] and to the right are the various [Engineering buildings]. The road goes in a big loop around [the campus] you can either go left [towards the Medical buildings] or right passed [the Engineering buildings] then head North (away from University square). One other area you may want to explore is [South Lawn] which you can get to by going [underneath the overpass building] directly in front of you when you enter [the campus]

This is an example taken from the set of campus descriptions. The triplets output by the program are shown in Table 3⁵. We observe that the triplets come up as desired. For instance, the program infers the complex triplet: < an entrance across Grattan Street from University Square > with its complete inherent information using the DLEs related to it, i.e. [Across Grattan street], [from University square] and [an entrance]. A spatial role modelling approach can’t seemingly capture such complex information. Again for formalising reasons, the ‘across from’ relation can be broken analogously to a ‘between’ relation in the previous example. It can be seen, however, that not all triplets were extracted by the program because of issues such as indirect references in the phrases “straight ahead . . . Engineering buildings” and “In the other direction . . .”, and spatial motion in the sentence, “The road goes . . .”, which are not dealt with currently by the parser.

5.3 Investigating Errors

From the results obtained by the test corpora, there was a clear indication that the validity of the produced triplets relies on the correctness of the Stanford typed dependencies,

⁵The first and the third sentence were split at clause boundaries to eliminate Stanford parser errors; see Section 5.3.2

Manual Annotations	Overall (%)		Static cases (%)	
	Accuracy	Recall	Accuracy	Recall
Yes	46.1	20.5	77.4	40.0
No	40.4	19.7	60.5	38.3

Table 4: Results of triplet extraction on campus descriptions. The static cases include those without spatial motion but with indirect references.

as well as the accuracy of the DLE parser. Some invalid cases are also the product of the subject finding methodology for the DLEs, mainly due to its inability to resolve indirect references and disambiguate the spatial sense in the subject. In other cases, it is the informal or incorrect usage of grammar that led to the failure of triplet extraction. Each of these cases are discussed in detail below.

5.3.1 Invalid Subjects

The errors corresponding to invalid subjects found can be prominently classified into two types: *invalid place name* and *subjects with unwanted information*. Since there is no spatial sense disambiguation done for the noun phrases, some of the subjects reported turn out to be invalid. For instance, in example 5, the subject of the DLE *along the street* is *approximately halfway* (a noun phrase) and is deemed correct by the program, producing an incorrect triplet. Similarly in example 7, subject of *at the gate and the house* is identified as *roses* (instead of *an arch*), which is not a place reference and thus is invalid. Such errors can be corrected by choosing subjects, which are identified as place references by the DLE parser. However, this leads to the side-effect of making the production of triplets heavily dependent on the accuracy of DLE parser.

Additionally, this approach of finding the subject of a DLE in the most informative way leads sometimes to extensions with undesired information. In the example 4, *Wilson Hall* gets undesirably extended to *Wilson Hall a multi-function hall*, due to having DLEs separated by a comma identified as a single expression. While in most cases this rule provides useful spatial information (e.g., the University of Melbourne, in Carlton), in the example provided here the expression after the comma does not add to the spatial sense of the DLE.

EXAMPLE 4. Next [to the sandstone core] is [Wilson Hall], a multi-function hall . . .

Triplet extracted:

<Wilson Hall a multi-function hall next to the sandstone core>

5.3.2 Limitations Of The Stanford Parser

The errors corresponding to limitations of the Stanford parser include incorrect POS tagging and hence, incorrect typed dependencies. Since, the backbone of the subject finding task are the typed dependencies, the major errors that occur in the extraction process are when the dependencies are incorrect. For instance, in example 5, the parser failed to realise the dependency between *private residence* and *along the street*. Some of the errors originate from the incorrect POS tags such as that in Example 3, where *diagonally* is identified as a noun (instead of an adverb), and thus an invalid triplet is produced.

EXAMPLE 5. *I am [at a private residence] located on the western side [of Barrington Avenue] [in Kew], approximately halfway [along the street].*

Triplets extracted:

```
<I at a private residence>
<a private residence on the western side of Barrington Avenue>
<Barrington Avenue in Kew>
<approximately halfway along the street>
```

The study of the error of these types led to an interesting observation. The major cases where the Stanford parser fails to identify the dependencies are those with long sentences containing multiple clauses. This can be fairly justified considering the inexhaustive training behind the Stanford parser. However, it can be seen that such long sentences have visible clause boundaries (usually separated by ‘;’) and if the clause boundaries are detected and the sentence is split into its clauses, the dependencies turn out correct. Clause separation was used whenever possible in the triplet extraction to eliminate dependency errors. Correcting the Stanford parser is clearly out of scope for this paper. However, for future uses, it is suggested to either retrain the parser to handle multi-clausal sentences, or alternatively, to preprocess the data by splitting the sentences at their clause boundaries, before feeding them to the parser.

5.3.3 Inaccuracy Of The DLE Parser

Since the task of DLE parser is to identify prepositions and the following place references, errors are related to the reported span of the DLE and the preposition’s spatial sense. Example 6 is a case where the lack of disambiguation of the preposition’s sense is exposed. The DLE parser identifies *at night* as a DLE although at here has no spatial sense, thus resulting in an invalid triplet.

EXAMPLE 6. *There is [constant construction] which keeps all residents up [at night].*

Triplet extracted:

```
<constant construction at night>
```

Next example (Example 7) highlights the case where an incorrect span of a DLE is reported. The triplet extracted is **<roses at the gate and the house>** instead of **<roses at the gate>**, because of the effect of the connector ‘and’ mentioned previously (Section 5.2).

EXAMPLE 7. *There is an [arch] with roses growing on it [at the gate and the house] is a double - [fronted Victorian house].*

As compared to the F-score of the DLE parser without the manual annotations (0.76), the F-score of the parser with annotations is very high (0.99)⁶ [21]. Though using manual annotations increases the overall F-score of the DLE identification, it is observed in some instances the recall increases when not using the manual annotations, at the expense of accuracy. With the manual annotations, the parser becomes strictly restricted to the annotated place references and a DLE gets identified only if the associated place reference is present in the annotations.

⁶Results indicated are related to identification of DLEs and not for extraction of triplets

5.3.4 Incorrect Grammar Usage

The informal or incorrect usage of grammar may become a major obstruction in the extraction of useful spatial information. This also includes the concatenation of sentences without appropriate punctuation. Unfortunately in such cases, neither the Stanford parser, nor the DLE parser is robust enough to avoid the errors.

5.3.5 Missing Triplets

The results of triplet extraction have a good precision in static place descriptions containing no spatial motion. But for the corpus as a whole, the inability of the approach to handle the limiting cases results in a low recall in terms of total expected triplets. For example, in Example 3, though about 80% of static triplets were extracted, only about 40% of the total expected triplets were reported. This outcome is understandable as the parser has no access to motion indicators and no specific approach targeting reference resolution.

5.4 Inability To Resolve Indirect References

The major obstacle found in the performance of our approach was its inability to resolve references. In a situated place description, people frequently make use of indirect references. The indirect references can be exophoric as well as implicit. For example, “*Near this cornering point, you occasionally find a crepes stand*” makes use of exophoric reference, but “*To the West is the Baillieu Library*” makes use of an implicit reference. Thus, the task of resolving indirect references subsumes the task of exophoric reference resolution and the previous well-studied domain to resolve exophoric references can not deal completely with these indirect references. However, it was observed that the indirect references used in human descriptions go in a depth-first fashion especially to describe descriptions involving path intersections. For example, in the description, “*there are three main alternative paths that you can use to head north. The central one is up some stairs [...]. The path will take you to the [...] where there is [...] and a little to the east, the Union House. Union House is a large building containing [...]*”. And then the reference ends and the speaker switches back to the other branch to explore a new depth, “*The second path [...] from the south entrance takes you a little bit to the west and then switches north [...]. Near this [...], you find a crepes stand. From this path [...]*” (here expressions like “this path”, “the road” represent the current reference). And then again it switches back, “*The third path [...]*”. However, if there is a single path to describe, it comes out as a tree with a single branch. Though intuitively simple to understand, the complexity behind this approach is to infer the decision of whether moving further on the depth of the tree or to add a new branch to the existing depth.[11]

6. CONCLUSIONS AND FUTURE WORK

This paper addresses the task of extracting spatial information from NL place descriptions by using triplet representations. We have come up with a simple, yet effective reasoning approach for understanding static place descriptions, without making use of any external resources such as maps, or path geometry. The attempt to find informative and computationally convenient triplets sets up a good potential medium for translating textual place descriptions to graph representations, such as automatically produced

sketch maps, as suggested elsewhere [26]. We have implemented the approach to two different corpuses, which were not mere set of spatial expressions, but situated place descriptions. Our experiments investigated the applicability of the approach and indicate a good recall for extracting static triplets for the production of triplets of a locatum, spatial relations and reference objects. It suggests that when the place descriptions contain a static structure in the spatial relationships and there are no indirect references, we can be confident of the reasoning approach to yield the triplets, given that the DLE parser has identified the DLEs correctly. We have made an extensive study into the shortcomings of the approach exposing the impact of absence of indirect reference resolution and spatial motion interpretation in understanding situated place descriptions.

The work reported in this paper presents an effort to enhance the Stanford parser, so as to accommodate the extraction of spatial information from natural language place descriptions. This research also forms the first attempt to use DLEs as an intermediate step to extract triplets from spatial language. Our experiments tested the DLE parser on a corpus different from the one it was originally trained for. And, our analysis on the results of DLE parser suggests that use of the DLE parser is well suited for understanding static place descriptions without any indirect place references. We also pose the need for learning the prepositional sense to improve the precision of such a parser meant to identify DLEs. Furthermore, we reveal that the Stanford dependency parser when used with place descriptions, errs in fundamental tasks of POS-tagging and extracting *typed dependencies*, and that the parser could achieve more reliable results if it is re-trained to work on sentences with multiple clauses. And it remains as a critical tool to explore spatial language further by aiming at descriptions involving motion.

Our attempt to understand place descriptions exposes several gaps in this research area. One obvious direction of extending the reasoning approach in this research and making it more robust is to migrate to a case based reasoning (CBR) approach [27]. CBR is a learning approach that works by forming generalizations of training examples, leading to a more natural mechanism for triplets extraction. A critical issue in triplet extraction is resolving indirect references which point to place names. Such references can occur using indicators such as ‘here’, ‘this’, ‘there’, ‘that’ or ‘it’. In some non trivial cases, there may be no explicit indication of the reference, but an implicit one in the context of the description. For instance, in “*In the center are the original ‘old’ buildings.*”, there is no way one can resolve the reference without storing the context from the corresponding situated description. Hence, there rises a need of an approach which keeps track of the context and enables grounding of such non-trivial references. Additionally, extracting spatial triplets from a description becomes more challenging with an egocentric frame of reference, e.g., “*Facing the activity center, you would find a tower on your left*”. One needs to figure out the relationship between *activity center* and the *tower* using the orientation set in the description and develop a generalized approach to deal with an egocentric frame of reference.

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