Applying ISO-Space to Healthcare Facility Design Evaluation Reports

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Abstract

This paper describes preliminary work on the spatial annotation of textual reports about healthcare facility design to support the long-term goal linking of report content to a three-dimensional building model. Emerging semantic annotation standards enable formal description of multiple types of discourse information. In this instance, we investigate the application of a spatial semantic annotation standard at the building-interior level, where most prior applications have been at inter-city or street level. Working with a small corpus of design evaluation documents, we have begun to apply the ISO-Space specification to annotate spatial information in healthcare facility design evaluation reports. These reports present an opportunity to explore semantic annotation of spatial language in a novel situation. We describe our application scenario, report on the sorts of spatial language found in design evaluation reports, discuss issues arising when applying ISO-Space to building-level entities and propose possible extensions to ISO-Space to address the issues encountered.

1. Introduction

Identification and interpretation of spatial information in natural language is a topic of increasing interest in contemporary computational linguistics. Newly emerging techniques in language processing, based on standards for annotating spatial language such as SpatialML (Mani et al., 2010) and ISO-Space (Pustejovsky et al., 2011a), are capable of automatically identifying location references in text and grounding them, e.g via geo-coordinates as supplied in a gazetteer. This grounding information supports fusion of text accounts with other digital applications.

Following the construction or significant refurbishment of healthcare facilities, qualitative methods are often applied by healthcare and architecture professionals to gather evidence about which aspects of the design have worked and which have not. These evaluative studies form important knowledge resources for future similar projects during their inception. However, current practice in disseminating evaluation studies often amounts to no more than distributing a limited number of hard copies of lengthy reports. This effectively limits access to the content of the reports, leading to the findings of such studies rarely contributing to best practice.

To address this problem we have initiated an investigation into Annotated 3D Interactive Navigation (**A3DIN**), to radically enhance the accessibility and readability of the evaluation study documents. The end goal is to build a software prototype from a fusion of 3D virtual architectural modelling and spatial language processing, applied to a small scale case study, that will allow a user to navigate from a particular passage in a textual design evaluation report to an appropriate illustrative view within a 3D model and vice versa. As one of the first steps in this process, we have assembled a small corpus of design evaluation reports and attempted to annotate spatial entities and relations in a subset of these texts in accordance with the ISO-Space semantic annotation guidelines. To the best of our knowledge we are the first to apply ISO-Space at the building/sub-building scale – all previous applications appear to have been at the urban, interurban and geographic scale as referenced in text types such as newswire reports and cyclist blogs[1].

In this paper, we report on work in progress within the A3DIN project. Specifically, we: (1) discuss the A3DIN scenario in more detail and the pilot study we are engaged in to investigate it (Section 2.); (2) describe our small corpus of design evaluation reports and present examples of the sorts of spatial language that characterise these reports (Section 3.); (3) present and analyze issues arising in the application of ISO-Space to the reports (Section 4.); (4) discuss related work (Section 5.); and (5) conclude with a summary of lessons learned and suggestions for adapting ISO-Space to work in this domain.

2. The Application Scenario

Healthcare buildings represent a significant investment and their design directly influences the functions they support – poor design can have a severe negative impact. A design approach both geared towards the needs of end users (through e.g. Design Quality Indicators) and learning from past experience (Evidence-based design) is therefore valuable. Post-Occupancy Evaluations (**POE**s) are recognised as important during building commissioning and use. Information garnered from these is an essential part of the evidence-based design process as well as a means of determining if design targets of the building being evaluated have been met. Despite this, the commissioning of POEs in the past has not been routine. There is a considerable body of post-occupancy information available, however it is quite variable in the nature of its content.

Worldwide, undertaking of POEs varies. There are records of POEs in the US dating back to the 1960s (Preiser et al., 1988) and POEs have been carried out for many building

[1] See Section 5. below or, for example, the annotations in LDC corpus LDC2008T03. There is a suggestion in Pustejovsky et al. (2011a) that the ISO-Space working group is investigating interior descriptions with a view to improving the specification to address them, but we are not yet aware of any published outcome of this work.

types: offices, schools, courthouses, prisons, housing and so on. Healthcare POEs are less common. This may in part be due to the status of healthcare building commissioning – for example, many EU countries with widespread state-funded healthcare (such as Sweden and Denmark) have not had hospital building programmes until now. Although POEs can be undertaken at any point in a building's lifetime, the most common point of undertaking is early in the building's use.

In contrast, the UK has built almost two hundred under a public-private initiative in the past twenty years. This increased the requirement for feedback and for learnings from POEs to be taken into consideration for subsequent construction projects. POEs are now mandatory in certain areas. As a result, the Department of Health in the UK has not only developed detailed healthcare guidance and design/evaluation tools (e.g. ASPECT/AEDET; UK Department of Health (2008a, 2008b)) to improve design quality but has also been instrumental in seeking to draw out lessons learned via post-project evaluations incorporating POE.

The UK is a special case where there is an established healthcare construction programme and also sophisticated post-occupancy evaluation methods, and where buildings recently constructed under the program have been occupied long enough for these methods to be applicable. This generates a situation where there is both a new type of evaluation report and also, with more hospital building programmes starting in other countries, broad demand for the information contained in such reports.

Despite such sophisticated methods for carrying out evaluation studies, current practice in reporting these studies, as noted above, often takes the form of bound paper-based documents, of which only a limited number of hard copies are made available due to the production cost. The accessibility of these reports is therefore quite limited and they do not contribute to wider adoption of best practice as revealed by these studies.

From a usability perspective, these evaluation reports are problematic for a number of reasons. First, despite inclusion of images and fragments of floor plans, it is frequently difficult to properly interpret the text without "seeing" the aspect of design under discussion in the visual context of the building. Second, for a reader interested in a particular part of the building or aspect of the design, or wishing to quickly ascertain the positive or negative features highlighted by the report, detailed perusal of a lengthy document may be required. Given the move by architects to use 3D modelling tools in producing designs of buildings, it is natural to ask if building documentation, such as evaluation studies, could be linked to the 3D models so that readers could move between the visual and textual mediums to faciliate better understanding and more flexible access to information. For example, a reader could point to the part or aspect of the building of interest and be shown the portion(s) of the report discussing it; good or poor aspects of the design could be highlighted directly in the 3D model, e.g., by use of colours, to provide a visual summary of the report that users could interact with to access more specific information in the report.

Manually linking texts and 3D models is not feasible in general, and thus the linking process needs to be automated. To automate this process requires a number of technical capabilities which do not exist at present, or are only just beginning to emerge:

1. the ability to recognize references to places, spatially situated entities and spatial relations in text;
2. the ability to associate semantic information with graphical elements in CAD-generated 3D models;
3. the ability to interpret spatial language in text in order to:
   (a) ground spatial referring expressions in the co-ordinate system of the graphical model;
   (b) model spatial relations holding between spatial entities (e.g. *The waiting area is adjacent to the courtyard*);
   (c) understand the viewpoint taken in the text (e.g. *As you enter the building the reception desk is easy accessible ...*)

   so as to present the correct portion of the model at the correct orientation and scale.

ISO-Space is an important step on the path towards achieving capabilities 1. and 3. Capability 2. is outside the scope of this paper, but is being addressed within the building design community, particularly through Building Information Modeling (**BIM**)[2] and the emergence of open standards to support BIM, such the Industry Foundation Classes model[3] which is in the process of becoming an ISO standard and is now implemented in open source tools such as BIMServer[4]. For present purposes, the key observation is that we can safely assume there will be some mapping between natural language terms and labels attached to semantic elements within a building design model, such as for instance room numbers or (possibly ambiguous) names for specially designed spaces, such as *waiting room*, *pharmacy*, *physiotherapy gym*, etc. These elements within the model are in turn associated with specific parts of the graphical representation of the 3D model which is itself positionally specified in terms of offsets from national survey benchmark points, thus indirectly grounding the whole model in the conventional geospatial co-ordinate system. From these mappings can be distilled the equivalent of a building-specific gazetteer – a resource mapping linguistic references to places within a building to portions of a 3D model and to spatial areas within the world.

To engage with this scenario we have chosen to investigate the design of a specific health care facility, the Jordanthorpe Health Centre in Sheffield, UK (Figure 1). We are in the process of building a 3D model for the site using Graphisoft ArchiCAD BIM software[5], with models exported to IFC

[2] See http://en.wikipedia.org/wiki/Building_Information_Modeling

[3] See http://www.buildingsmart.com/

[4] See http://bimserver.org/.

[5] See http://www.graphisoft.com/products/archicad/.

Figure 1: The Jordanthorpe Health Centre

format files, and have a collection of design evaluation reports about it, written by Masters level students from the School of Architecture, University of Sheffield. We also have detailed floor plans for the facility and are creating a "building gazetteer" from these to serve as a temporary 2D grounding target for spatial language recognition while the 3D model is being developed (linking textual content to a 2D floor plan representation is itself a challenging and worthwhile goal, as some textual observations are better illustrated by a 2D view from above, than from a 3D view from within).

3. Spatial Language in Design Evaluation Reports

To investigate the sorts of language used in design evaluation reports we have assembled a small corpus of four reports in English written by students from the School of Architecture, University of Sheffield, as part of their professional training[6]. These reports are shorter than those typically created by practising professionals, but otherwise are entirely realistic as they are created using the guidance and instruments recommended by the UK Department of Health. The documents range from 18 to 38 pages including images, or about 3000-10,000 words. They follow a standard report format and contain mainly evaluative and descriptive statements concerning aspects of the building design. As such, they are a particularly rich source of spatial language. Key features we observed in these reports include the following.

3.1. Multiple Scales

The majority of sentences in the reports contain expressions which refer to locations and entities at or below the level of the building, describing both the interior and exterior spaces of the site, for example: entrance, corridor, building interior, wall, ceiling, waiting area, door, windows, car park etc. (see example (1)). However, we also find expressions relating to locations and entities above the building level, such as counties, regions, cities, streets etc. (see (2)). There are also examples, such as in (3), of references to astronomical bodies (e.g. the sun).

(1) *The main entrance to the building is located in a corner under an overhang, which does not allow it to be visible to patients easily.*

(2) *The Jordanthorpe area is situated in the Southwest of the city of Sheffield, close to the border with Derbyshire.*

(3) *The sun rises in the morning behind the centre and moves in the direction shown on the sun path diagram below ...*

3.2. Multiple Perspectives

We find various types of location expressions, which reflect different perspectives on a space. For example, we can distinguish between:

1. terms referring to concrete architectural elements, e.g. *building*, *rooms*, *main entrance*, *corridor*, *car-parking spaces*, *windows*, *façade*, etc. Such terms may indicate function, e.g. *consultation rooms*, *main reception*, *patient female WC*, and often correspond to names in the associated floor plan.

2. more abstract expressions referring to areas or zones. These are typically (but not necessarily) labelled according to the function of the space or the category of intended user, e.g. *waiting area*, *parking area*, *designated queueing area*, *patients activity zone*, *staff only zone*. Such references often correspond to labelled areas in the building plan and we find they refer to multiple or partial spaces as denoted by the kind of references we refer to in 1.

3. expressions in the texts where these different perspectives are mixed and presented in relation to each other. For example:

   (4) *... the waiting area on the first floor has a great view of the courtyard as well as the front yard and the woods nearby.*

   (5) *The immediate interior area around the entrance feels reassuring because it is open and airy.*

Thus we see a complex mix of formal vs. functional terms, viewed at varying levels of granularity.

3.3. Spatial Relations

The reports contain a particularly rich set of spatial relation expressions. These include expressions relating the positions of locations or spatial entities to each other:

(6) *For example, the bottom corner of the pillar to the right of the entrance has a small area where the render is missing.*

(7) *The entire health centre is surrounded by a fence approximately 2m in height.*

[6] Reports were conducted under the Module ARC6810 "Architecture and the Design Process" during 2009-10 and according to University of Sheffield Architectural Healthcare Environment Research Group standards.

and also expressions relating other spatial aspects of entities, such as their relative size or their distance from each other (sometimes including measures):

(8) *These buildings, shown photographed from across the car park in Figure 4.2, are substantially smaller than the health centre ...*

(9) *The bus stop is a very short walk (approximately 30m) from the main entrance.*

3.4. Direction, Orientation and Viewpoints

In addition to the spatial relations just discussed, there are frequent examples of expressions which indicate compass direction or orientation. This may be the orientation of a particular entity/location, e.g., (4) above and also:

(10) *The front of the centre, where the main entrance is situated, faces towards the west.*

(11) *Most of the windows in the consultation rooms overlook the courtyards*

We also find examples of references to entities or locations which can be viewed from a particular position, and possibly via another: (a) viewed from (b), via (c)

(12) *View from the waiting area towards reception, showing the mezzanine floor, which adds interest to the interior form.* (a photo caption)

(13) *For example, the entire south façade of the building is fully glazed. This provides a view of both the ground and sky, a key design feature.*

3.5. Movement of Entities in Space

While the design evaluation reports are very rich in references to locations, spatial entities and their spatial relations, there are relatively few descriptions of motion (it is, after all, a static entity that is being evaluated). However there are some. These tend to refer either to the movement of light or air, or to paths patients will follow in using the facility. In both case reference is not a specific event (of air entering or of a patient moving) but rather of regular occurrence of events of a particular type.

(14) *As cold air can easily penetrate through the windows ... it can affect occupants thermal comfort.*

(15) *It is the first area that visitors will arrive at when using the car park or nearby bus stop.*

3.6. intentional Contexts, Modality, Negation and Conditionality

In contrast to the expressions which indicate the intended or actual function of a space, we also find expressions which indicate expected or believed consequences of design decisions, possible future use, the absence of things in space and conditional expressions, or combinations of several of these (cf. examples (16) and (17)), particularly in evaluative passages in the reports when missing features or alternative possibilities overlooked in the design are being pointed out.

From a linguistic perspective we see intentional contexts:

(16) *It is expected that the lack of blinds available to exclude sunlight could cause discomfort to both patients and staff.*

(17) *The author suggests that the bid to let the space as a café may have been more successful if the café had a separate entrance to the main health centre and was more outward-facing.*

modal expressions:

(18) *For example, the space behind the sculpture could be used for outdoor seating in the summer and passers-by would be able to see that there was a café available in the area.*

(19) *It would possibly be more appropriate to situate the health centre to face towards the south-west ...*

negated expressions or expressions noting absence:

(20) *There is no sign of art works in the corridors and stair cases creating a very monotone environment.*

(21) *... the lack of these views is a flaw in the design of the health centre.*

and finally conditional expressions noting things at could have been done differently or could be altered in the future.

(22) *If more green features such as trees and plants had been used in the court yards a better feeling of being in nature could have been encouraged in users of the building.*

(23) *However, if in the future the courtyards are made available to patients this may become a more serious problem.*

4. Annotating Design Evaluation Reports with ISO-Space

To better understand issues relating to the application of the ISO-Space annotation specification to building design evaluation reports, we began by selecting two of the four reports in our corpus to annotate. Using the ISO-Space annotation specification described in Pustejovsky et al. (2011a; 2011b), a human annotator added ISO-Space markup for locations, spatial entities and spatial signals to the reports, adhering to the guidelines as stricly as possible. In total, two reports were so annotated. Table 1 contains summary statistics of the annotated data. Following this we reviewed the annotations in the light of our intended application and made the following observations, some of which lead to proposals to extend or adapt ISO-Space for use in a broader range of applications.

4.1. Location vs. Spatial Entity

In ISO-Space a key distinction is that between *location* and *spatial entity*[7]. A location is characterised as "an inherently

[7] In SpatialML, what became the ISO-Space location element was a place element. In the latest unpublished version of the ISO-Space specification, version 1.4c, locations have been subdivided into two sorts, place and path, so "place" has reappeared at the preferred term for what Pustejovsky et al. (2011a), and we in the following, will refer to as location (Pustejovsky, personal communication, 2012).

Feature	Count
Words	13 052
Spatial entities	503
Locations	26
Spatial signals	84
Events	6
Motions	2

Table 1: Summary of ISO-Space element counts in annotated documents

grounded spatial entity", with exemplars being things like countries, mountains, cities and rivers (Pustejovsky et al., 2011a) – the sorts of named things one typically finds in geographical gazetteers. By contrast a spatial entity is "an entity that is not inherently a LOCATION, but one which is identified as participating in a spatial relation", examples being *car*, *building* or *John* or event-like things such as *traffic jam* or *hurricane*. Further to this, Pustejovsky et al. (2011a) say:

> Each SPATIAL_ENTITY inherently defines a location and can be the location for other spatial entities, as in *John is in the car*. This raises the issue of whether entities like *building* in *The statue is in the building* are annotated as locations or spatial entities. We resolve this by stipulating that these entities are never annotated as locations but always as spatial entities, even in a case like *the president is in the building*.

Following this instruction, in our first pass at annotating two of the Jordanthorpe design evaluation reports, we annotated all references to the building and to parts of it or things within it as SPATIAL_ENTITIES. This led to the relative proportions of these two types seen in Table 1.

However, on reflection we began to question whether this was the correct choice. If we ask what "inherently grounded" (the proposed defining characteristic of locations) means we see that there is no straightforward answer. If it means "has a fixed set of geospatial co-ordinates over an extended time period", then there is the difficulty of specifying precisely how long the extended time period should be. If it is too long then this definition fails to admit things that would seem to be locations, such as mountains and islands in Iceland that have formed recently (e.g. Surtsey Island, formed in 1963, or Eldfell, the mountain formed in 1973) and furthermore there will be difficulties with continental drift which, over an extended time period, leads to geospatial coordinates of landscape features, such as mountains and rivers – things which we might normally unquestioningly think of as locations – changing. On the other hand if a time period which is too short is chosen then various things, such as very old trees or ancient monuments (Stonehenge, Westminster Abbey), would seem to qualify. Furthermore extra-terrestrial bodies such the moon or indeed the rest of the Universe, which have a good claim to be considered locations, are also excluded. Another analysis might be "has an entry in a geographical gazetteer". This also seems unsatisfactory in that gazetteers may well be missing some entries, unnamed geographical features that are just like others which do have names and are in gazetteers get excluded, celestial locations are again excluded, and so on.

The task of providing a philosophically satisfactory account of the difference between locations and spatial entities is indeed a challenging one, and not one that we are going to attempt. However, we wish to advance a pragmatically motivated proposal that we believe usefully generalises the ISO-Space model. Rather than assume, as the current ISO-Space model appears to do, that a location is something that is fixed in space and across time, a more flexible approach would be to acknowledge that what constitutes a location will vary depending on the spatial and temporal scale adopted in a particular discourse. We believe that two two related, fundamentally sound intuitions about the distinction between locations and (other) spatial entities are as follows:

1. locations are (relatively) positionally stable entities in the spatial frame of reference for the discourse we are trying to analyze, whereas other spatial entities tend to move about within the frame of reference in a time scale during which the locations remain fixed;

2. the sort of things that appear in gazetteers are the names of locations (at the spatial and temporal scale for which the gazetteer is appropriate – presumably because it is the names of the things that are relatively positionally stable at the appropriate scale that find their way into gazetteers).

We also believe that in the context of semantic annotation there are two requirements on any distinction between tagged elements:

1. any distinction between classes of annotated textual elements should serve some purpose in some intended application of the annotation;

2. any distinction should be clear enough that annotators can easily and reliably recognize it.

One obvious purpose that locations serve in the sorts of applications used to motivate SpatialML and ISO-Space is that of being the entities linked to gazetteers and to geo-coordinates. I.e. it is locations that allow texts to be linked to other, graphical forms of representation via links to gazetteer database entries or via geo-coordinates. In our application scenario, the linking we are interested in is that from building elements to a 2D or 3D graphical model of the building. Thus, the pragmatic position we take is that we should allow building elements that can be mapped via the sort of "building gazetteer" mentioned above in Section 2. (rooms, stairways, named functional areas and so on) to be locations. This fits with our intuitions that locations be relatively stable and be the sorts of things whose names appear in gazetteers or maps of some terrain. By contrast, spatial entities are things that may move around in locations (such as furniture, art work and plants).

Thus, our first proposal to extend ISO-Space to support a broader range of applications is to clarify the distinction between locations and spatial entities, clarify the role that grounding plays in identifying locations and allow grounding not just at the scale of geographic features and geo-coordinates, but at whatever scale is appropriate for linking the text to 2D or 3D co-ordinate or map/model based representation of the spatial world being described in the text and for which external models exist. Concrete suggestions on how to do this within the syntax of ISO-Space are discussed in the next section.

4.2. Multiple Scales and Frames of Reference

As discussed above in Section 3.1., a single building design evaluation report will frequently talk about the spatial properties of buildings at different scales. Thus, the site of the building within the broader urban or geographical setting will be discussed, as will, e.g., details of room positions within the building.

While descriptions at different scales may be specified within the same co-ordinate system, they need not be. Thus, a building might be located within a city using lat-long coordinates, but a BIM or CAD representation of the interior might take as an origin some arbitrary point within the building (e.g. lower left corner when viewed from the front). Building elements, such as room positions, for example, within the building will then be defined in the building co-ordinate system.

In this case, if the building co-ordinate system origin can be given a lat-long co-ordinate, perhaps via a nearby survey benchmark, then the building co-ordinate system can be embedded in the geo-co-ordinate system. In general, however, there is no reason why the multiple co-ordinate systems referenced in a document need to be such that one is embeddable in the other. The relation between them might be unspecified or the spaces they define may be non-intersecting or moving in relation to each other (imagine a story that alternates between describing activities on a planet's surface and on a space station orbiting the planet).

The term "frame of reference" is used in physics to describe a co-ordinate system which can be used to describe the position and motion of entities within it. Frames of reference can be embedded within each other or in motion in relation to each other. In order to deal with texts that involve multiple frames of reference, or even single frames of reference other than the base geo-co-ordinate frame of reference assumed currently in ISO-Space, we believe the ISO-Space model needs to be generalized to incorporate some such notion. Of course, "frame of reference" is already used in ISO-Space, and more broadly by cognitive linguists, to distinguish the types of orientation relation that are found in language systems – i.e. absolute, relative or intrinsic. We are not arguing to replace the linguistic usage with the physics one in ISO-Space, just to point out that this other sense is also relevant and should be incorporated into a framework for talking about the multiple levels of spatial description which occur in certain document types.

If we think of a gazetteer (or something like a map, floor plan or 3D model) and its associated co-ordinate system as providing a "frame of reference", then we need to be able to associate more than one frame of reference with a document. In fact, it is individual locations that are associated with frames of reference and therefore we need in principle to be able to associate a distinct frame of reference with every location mentioned in the text. In our view, therefore, the specification of the attributes associated with a location should be generalized to include a frame of reference attribute (in the physics sense). Of course the range of attribute values to be associated with certain attributes of location entity will depend on the frame of reference chosen. So, for example, the gazetteer reference will be to a gazetteer appropriate for frame of reference and the admissible location types will be frame of reference dependent (while possible types at the geo-level are, e.g. "continent", "body of water", and so on, at the building level appropriate types might be, e.g. "room", "corridor", etc.). These changes could be accommodated with relatively minor alterations to the existing syntax of ISO-Space.

4.3. Spatial Expressions in Intentional, Modal, Negated and Conditional Contexts

As noted in Section 3.6., there is a rich selection of cases where spatial expressions occur within intentional, modal, negated or conditional contexts. While these contexts are by no means predominant in the design evaluation reports, they occur sufficiently frequently that they cannot be ignored. In particular any algorithm processing spatial expressions in such contexts cannot assume either that the locations or spatial entities mentioned within them exist (though they may) or that the relations proposed between them actually hold. So, for example, in example (17), if *separate entrance to the main health centre* were tagged as a location, there would be no point trying to ground it in relation to the building gazetteer, because the entrance does not exist; in example (19) the health centre and the south-west are bona fide locations, but the orientation relation mentioned (*face towards*) does not hold between them. On the other hand such contexts may include spatial expressions that denote real locations and grounding them is important for our intended application of linking the reports to a 2D or 3D graphical representation to help readers better understand the text by "seeing" the context. For example, example the blinds mentioned in example (16) above are introduced two sentences earlier in the text by the negated intentional construct

(24) *There did not appear to be any blinds available to cover the high level windows and the double-height glazing at the end of the waiting area and surrounding the courtyards.*

but here the spatial entities (*the high level windows and the double-height glazing*) and locations (*waiting area* and *courtyards*) are real and should be grounded to allow an application to display a view of the relevant portion of the building.

At present there is no facility within ISO-Space to deal with these cases, though the problem has been noted in Pustejovsky et al. (2011a) as a topic for future work. Similar issues arose and have been addressed in the development of TimeML (Pustejovsky et al., 2003), one of the standards

contributing to ISO-Space, for the related problems of annotating temporal expressions and events within negated, modal, conditional and intentional contexts. We do not attempt to review that work here, but believe that parts of the solution developed there can be re-used to address some of the problems highlighted here. In particular the SLINK tag which was used in TimeML to mark sub-ordinated contexts, i.e. modal, conditional and intentional contexts, could be used here as well. Tagging such sub-ordinated contexts at least serves to flag the fact that spatial expressions and relations within these contexts need to be treated specially, as they may not reflect what is the case. At this point we do not have an analysis that distinguishes those spatial expressions within sub-ordinating contexts that do genuinely refer to those that do not – this problem remains to be investigated.

Aside from sub-ordinated contexts, there are also straightforward cases of negation – see examples (20) and (21). These frequently reflect the non-existence of a spatial entity, e.g. *no blinds*. For such cases, a simple solution might be to add a POLARITY attribute to the *spatial_entity* tag, in the way that TimeML associates a POLARITY attribute with the EVENT tag (this can be one aspect of a more general similarity between spatial entities and events as things that occur in space and time respectively). Less clear is how to handle references to absence of functional spaces in cases like *there is no small waiting area for those who require privacy* or to abstract spatial entities like views (*lack of views*).

In sum we propose that the ISO-Space specification address sub-ordinating contexts containing spatial expressions by explicitly confirming the inclusion of the SLINK tag. Further we suggest that a POLARITY attribute be considered as a mechanism to address assertions of the non-existence of a spatial entity. More work remains to be done to analyze difficult cases of negation and sub-ordination.

4.4. Identity and Coreference

Given that the focus of design evaluation reports is frequently on spatial aspects of the buildings being evaluated, locations and spatial entities are frequently in grammatically focal positions in sentences and are referred to across multiple sentences. This introduces all the well-known problems of coreference in natural language texts, including anaphora, varying definite descriptions, etc. Linking these multiple references to the same entities is essential for understanding, for example, what part of a building an evaluative statement may refer to (for example *the centre* and *the building* in examples (10) and (13) respectively cannot be grounded with recognizing that they refer to the Jordanthorpe Health Centre.

At present there appears to be no way to link multiple references to the same location or spatial entity. The closest relation in the current ISO-Space specification is RCC8 EQ for "equal" (Randell et al., 1992). However, this relation is ambiguous as to whether the entities it co-ordinates are the same object or are separate entities have the same spatial bounds. An identity relation would support co-referential spatial descriptions, and disambiguate two mentions of the same object from two objects with the same bounds. A similar problem was encountered in TimeML where a distinction needed to be made between distinct but *simultaneous* events and multiple references to the same event. There it was solved by introducing an IDENTITY relation type in addition to an SIMULTANEOUS relation type. A similar solution could be adopted in ISO-Space by, e.g. adding an ID relation type, distinct from the EQ relation type already present in the RCC8 set, to the set of allowable relation types on the qualitative spatial link tag.

5. Related work

The closest prior work on spatial annotation at the level we have investigated in this paper is by Blaylock (2011) who explores the general problem of describing street-level objects and events. Prior work on automatic annotation of both entities and links has examined mostly geographical entities (Mani et al., 2008) and generic approaches to spatial relation labelling (Shen et al., 2009). Some previous work has been carried out on linking spatial descriptions to visual representations in Barker and Purves (2008), who address the problem of analyzing photo captions in order to geo-reference the image.

Extracting terminology related to buildings has been examined thoroughly (Meyer, 2001). Wonka et al. (2003) presents a formal building construction grammar based on English terminology. Recently there have been efforts to build ontological models of architectural and construction related concepts and terms (Eliseo et al., 2011; Bhatt et al., 2011).

6. Conclusion

In this paper we have introduced a novel application scenario for the annotation of spatial information in texts – the annotation of design evaluation reports for health care facilities. On the practical side this scenario is motivated by the desire to link texts to graphical representations such as maps or 3D models in order to improve their comprehensibility and to support novel access and summarization capabilities. However, aside from being a compelling application scenario, this scenario offers new challenges for standards for spatial annotation such as ISO-Space because the documents in the domain are so rich in spatial language and because the scenario requires the application of the standard at a scale not yet investigated. We illustrated this challenge by cataloguing some of the wide range of spatial language found in design evaluation reports. We went on to describe preliminary work on annotating several design evaluation reports using ISO-Space. This effort exposed some fundamental issues that arise when applying the ISO-Space specification to documents discussing spatial locations, entities and relations at the scale of buildings and in the context of an application which requires grounding this information in an externally supplied model. From our analysis of these issues we proposed four extensions to the current ISO-Space specification:

1. a more nuanced description of the distinction between locations and spatial entities that will allow locations at other than the geo-centric scale implicit in the description of the standard so far and will enable clear-

cut decisions to be made by annotators, perhaps operationalising the distinction in terms of what can be grounded by reference to a specific external resource relating named entities to a co-ordinate system;

2. an explicit encoding of something like a frame of reference attribute that will support interpretation documents that contain spatial descriptions in multiple frames of reference – other attributes of locations, such as type and gazetteer reference, would then need to be interpreted in relation to the specified frame of reference, and their admissible values would depend upon that frame of reference;

3. an explicit acknowledgement that something like the TimeML SLINK should be used to identify spatial expressions that occur on sub-ordinated contexts, such as modal, intentional and conditional contexts and that something like the TimeML POLARITY attribute should be added to spatial entities so that assertions that deny their existence can be properly encoded;

4. the addition of something like an ID relation to the set of qualitative spatial link types, distinct from the EQ relation, in order to distinguish multiple references to the same spatial entity or location from references to multiple spatial entities or locations occupying the same place.

Turning to the future, our plan is to annotate fully our small corpus of design evaluation reports with an extended version of ISO-Space that takes into account the proposals above. There are no doubt additional challenges to be addressed in applying ISO-Space, as we move to add spatial links and to deal with the sorts of examples discussed in Section 3.2. on multiple perspectives, such as expressions referring to functionally specified areas (e.g. a *staff-only zone*). Following this we will begin to develop tools to support automated annotation and grounding and then to integrate the language processing components with 3D graphical representations in order to address the complete application scenario. Finally, moving beyond design evaluation reports there is a huge range of other similar applications relating textual documents to designed objects.

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