Spatial interpretations of prepositions

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Goals of this talk

- How do we derive **spatial interpretations of prepositions** from large corpora.

- Additional requirements for the use of **spatial interpretations** in **situated contexts,** as e.g. communication with robots.

Linguistic and non-linguistic descriptions of spatial relators

- **Prepositions** are prime candidates to encode **spatial relations.**

- They serve for spatial orientation, movement, and trajectory.

  - **vor** ('in front of') vs. **hinter** ('behind'); **in** ('in') vs. **aus** ('from'); **über** ('over', 'above') vs. **unter** ('under', 'below'); **über** ('across') vs. **durch** ('through')

- Myth has it that prepositions come in different flavours (spatial, temporal, causal, modal, …).

Interpretation	Prototypical spatial prepositions										
	an	auf	bei	durch	gegen	hinter	in	neben	über	unter	vor
spatial	•	•	•	•	•	•	•	•	•	•	•
temporal	•	•	•		•		•		•	•	•
causal		•	•	•					•	•	•
conditional			•	•			•			•	
purpose		•									
concessive			•								
consecutive							•				
modal/manner		•	•	•			•		•	•	
circumstance		•	•				•			•	
medial		•		•			•		•	•	
instrumental	•	•		•			•		•	•	
participation										•	
correlation										•	
statement							•				
state							•			•	
hierarchy									•	•	

Domain-specific polysemy

■ Domain-internal polysemy must be taken into account.

– It does not help much to say that a preposition is "spatial".

(1) die Schrift **auf** dem Schild (the lettering **on** the sign; boundary area interpretation)

Reference Object (RO) and localized object (LO) cannot be clearly separated; LO is part of RO.

(2) Die Ameise sitzt **auf** der Wand. (the ant **on** the wall;

proximal area interpretation)

LO in proximal contact area of RO, no verticality involved.

Inferences differ!

(3) Die Tasse steht **auf** dem Tisch. (the cup **on** the table; vertical interpretation)

LO in the proximal contact-area of the RO; vertical axis involved

Further spatial interpretations

- Also, we would like to distinguish the aforementioned **spatial** senses from a further **spatial** interpretation of *auf,* which is near-synonymically related to a **spatial** sense of *in.*

    (1) Es befanden sich US-Truppen **auf** kambodschanischem Gebiet.
    there were   refl US troops   on Cambodian   territory

    (2) Es befanden sich US-Truppen **in** kambodschanischem Gebiet.
    there were   refl US troops   in Cambodian   territory

Inferential vs. conceptual differences!

Preposition sense annotation may appear to be a simple task ...

- Simple prepositions are closed class items, and hence defining all possible senses amounts to the following formula: if there are **n** prepositions and **m** senses then the total set of preposition senses consists of $n \times m$.

- Many prior attempts failed.

  - Preposition Project (Litkowski and Hargreaves 2005, English)
  - PrepNet (St. Dizier 2005, French)

- Some reasons

  - failure to identify a proper starting point (there is much less controversy regarding **n** than regarding **m)**
  - no relations between senses, no relations between forms
  - ignorance of MATTER

No proper start: dictionaries as guidelines

- **an** [an]: **I.**<Präp.> **1.a)** <mit Dativ; Frage: **wo?**> dient dazu auszudrücken, dass etwas ganz **in der Nähe von** etwas ist, etwas berührt: die Leiter lehnt an der Wand; Trier liegt an der Mosel; sie standen Schulter an Schulter *([in großer Zahl] dicht nebeneinander)*; sie wohnen **Tür an Tür** *(unmittelbar nebeneinander)*; <in der Verbindung «an...vorbei»> er hat sich an dem Portier vorbei hineingeschlichen. **b)** <mit Akk.; Frage: wohin?> dient dazu, eine Bewegung auf etwas zu, in eine bestimmte Richtung zu kennzeichnen: die Leiter an die Wand stellen; sie trat an die Brüstung. **2.** <mit Dativ; Frage: wann?> dient dazu, einen Zeitpunkt zu bezeichnen: an Ostern; an einem Sonntag. **...** (Duden Deutsch als Fremdsprache 2002, 81)

- Some indications of a guideline: *wo, in der Nähe von (close by)*

- No discernible specification: we cannot identify items that distinguish **an** from **bei.**

- The very general *(close by)* is mingled with the very specific *(Tür an Tür).*

	Static localization	Route
'boundary area'	**auf** *Die Schrift auf dem Schild* 'The lettering on the sign'	**über** *Die Schrift zieht sich über das Schild.* 'The lettering stretches over the sign.'
'proximal area'	**auf** *Die Ameise sitzt auf der Wand.* 'The ant is sitting on the wall.'	**über** *Die Ameise krabbelt über die Wand.* 'The ant is crawling over the wall.'
'vertical' +support	**auf** *Die Tasse steht auf dem Tisch.* 'The cup stands on the table.'	**über** *Er schiebt die Tasse über den Tisch.* 'He pushes the mug over the table.'
'vertical' - contact	**über** *Die Lampe hängt über dem Tisch.* *'The lamp hangs above the table.'*	**über** *Er wirft den Ball über den Tisch.* 'He throws the ball over the table.'
'inside' <3 relevant dimensions	**auf** *Sie stand auf der Wiese.* 'She was standing on the meadow.'	**über** *Sie geht über die Wiese.* 'She walks across the meadow.'
'inside' 3 relevant dimensions	**in** *Hans steht in der Straße.* 'Hans is standing in the street.'	**durch** *Hans läuft durch die Straßen.* 'Hans walks through the streets.'
'inside' <3D margin	**in** *Petra steht im Kreis.* 'Petra is standing in the circle'	**durch** *Petra lief durch den Kreis.* 'Petra ran through the circle'

MATTER

- … stands for: **M**odel, **A**nnotate, **T**rain, **T**est, **E**valuate, **R**e-Model (Pustejovsky and Stubbs 2012)

- Annotating senses is a time consuming, tedious task, and one cannot expect to get through annotating only once.

    – Different meanings might not been different after all (reduction of senses).
    – Meanings may be missing (addition of senses).
    – Proper senses may be distinguished from contextually enriched interpretations (identification of senses).

Bochum Spatial Decision-Tree Annotation (BSDA)

- BSDA (**B**ochum **S**patial **D**ecision-Tree **A**nnotation, Müller, Roch, Stadtfeld and Kiss 2011, Müller 2013, Müller and Roch 2013) serves as part of an annotation scheme for German preposition senses.

  - **BSDA employs decision-trees as implementations of the specification, and as a guideline at the same time.**
  - **The decision trees are implemented in MMAX-2 (Müller and Strube 2006).**
  - Preliminary inter annotator study (Müller et al. 2010) showed results between 0.65 and 0.8.

- **Goal**: An annotation scheme for a subset of 22 German prepositions as a **gold standard** for preposition senses.

  - *an*, *auf*, *bei*, *dank*, *durch*, *für*, *gegen*, *gemäß*, *hinter*, *in*, *mit*, *mittels*, *nach*, *neben*, *ohne*, *seit*, *über*, *um*, *unter*, *vor*, *während*, and *wegen*
  - http://www.linguistics.ruhr-uni-bochum.de/prepositions/

spatial ☐

temporal ☐

conditional ☐

Trotzdem setzte sich der Spanier am Dienstag auf sein Rennrad und quälte sich ** über die Strecke **.

'Nevertheless, the Spaniard got on his racing bike on Tuesday and struggled over the course.'

spatial ☒

    static ☐

    route ☐

temporal ☐

conditional ☐

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'Nevertheless, the Spaniard got on his racing bike on Tuesday and struggled over the course.'

spatial ☒

   static ☐

   route ☒

   RO* is   inside RO ☐

           in the boundary area of the RO ☐

           outside the RO ☐

temporal ☐

conditional ☐

Trotzdem setzte sich der Spanier am Dienstag auf sein Rennrad und quälte sich ** über die Strecke **.

'Nevertheless, the Spaniard got on his racing bike on Tuesday and struggled over the course.'

spatial ⊠

    static ☐

    route ⊠

    RO* is   inside RO   ⊠

                relevant dimensions   three   ☐

                                       less than three ☐

                in the boundary area of the RO ☐

temporal ☐

conditional ☐

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spatial ☒

    static ☐

    route ☒

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              relevant dimensions   three   ☐

                                    less than three ☒

              in the boundary area of the RO ☐

temporal ☐

conditional ☐

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Turning BSDA into rules

(1) die Schrift **auf** dem Schild ('the lettering on the sign')

(static, RO* is in the boundary area of RO) $\Rightarrow$ *auf*

(2) Die Schrift zieht sich **über** das Schild. ('The lettering stretches over the sign.')

(**route**, RO* is in the boundary area of RO) $\Rightarrow$ *über*

(3) Sie stand **auf** der Wiese. ('She was standing on the meadow.')

(static, **RO* is inside the RO**, < 3 relevant dimensions, RO defined over inner area) $\Rightarrow$ *auf*

(4) Hans steht **in** der Straße. ('Hans is standing in the street.')

(static, RO* is inside the RO, **3 relevant dimensions**) $\Rightarrow$ *in*

(5) Petra steht **im** Kreis. ('Petra is standing in the circle')

(static, RO* is inside the RO, **<3 relevant Dimensions, RO defined over its margins/ boundaries**) $\Rightarrow$ *in*

(6) Petra lief **durch** den Kreis. ('Petra ran through the circle')

(**route**, RO* is inside the RO, <3 relevant Dimensions, RO defined over its margins/boundaries) $\Rightarrow$ *durch*

Production, Perception and Annotation

- Annotating senses differs from employing senses in a face-to-face communication(production and reception).

- BSDA is build for the **annotation** of preposition senses.
  - Rules are derived from annotations and will only include information that is present in the corpora.

- Information is presupposed or left unspecified once an utterance turns into a sentence in a corpus.
  - functional information
  - reference frames
  - conceptualization

- Information might be necessary to decide for a sense/form in a face-to-face communication.

Functional Information
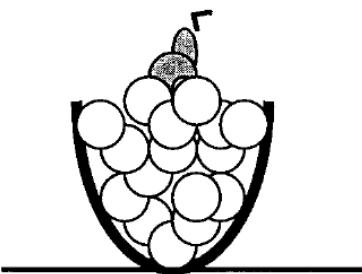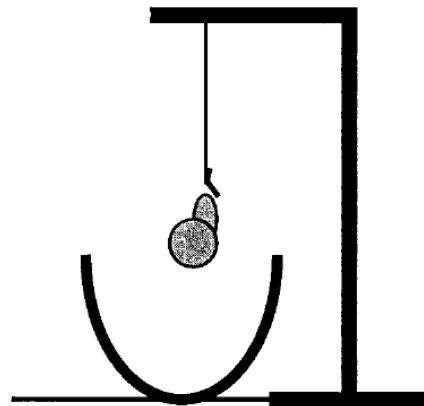
(a)   (b)

the pear in the bowl

Similar geometric but different functional relationship between pear and bowl

- Description fits (a), but …

- … is less appropriate for (b)

Functional influence

- Logan and Sadler (1996) found that the prototypical **above** relationship is
  - at a point higher than and directly above the reference object
  - in line with the center of mass of the reference object

- Displacing the figure from the central axis of the reference object reduces the appropriateness of the term (e.g. usage of another preposition with another sense becomes more likely).

- However: studies only involved abstract geometric shapes rather than real objects with any relations between them (Coventry et al. 2001, 378)

Functional information

- Appropriateness of the object to fulfill a given functional relation has an influence, too

  – *Wasser **in** einer Schüssel vs. **auf** einem Teller*
  water in a bowl vs. ?*water in a plate/water on a plate*

- Functional relations do not influence every preposition to the same extent:
  – Coventry et al. (2001): *over/under* were found to be more influenced by functional relations than *above/below*; *above/below* were found to be more influenced by geometrical relations than *over/under*

- Differences among languages:
  – in German *above* and *over* both can be translated into *über*, while *below* and *under* both correspond to *unter*
  – so what about functional and geometric influences for *über* und *unter*?
  – in preparation: experiments to investigate similar influences to the German prepositions *über* and *unter*

Functional relations and prepositions

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- Differences among languages:
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Functional information and annotation

- During the annotation, (if not made explicit) it is not possible to encounter whether or to which extent a functional relation determines the use of the preposition.

- Since there is no further information, we can only annotate the (prototypical) geometrical situation, and claim that a prototypical situation obtains.

Conceptualization

- The way we conceptualize objects in our world influences the use of prepositions

He walks over the meadow. ≈ *He walks through the meadow.*

He walks over the house. ≠ *He walks through the house.*

over → two dimensional concept
through → three dimensional concept

over → three dimensional concept
through → three dimensional concept

Conceptualization

During the annotation the preposition and our world knowledge can give us a hint

World knowledge: 'area' allows and two- and three-dimensional conceptualizations, 'building' not

*Das Tier wird nun **in/auf einem Areal** des vietnamesischen Forstministeriums beobachtet.*
The animal now is observed in/on an area of the vietnamese ministry of forestry.

    on   → two dimensional concept
    in   → three dimensional concept

*Das Tier wird nun **in/auf einem Gebäude** des vietnamesischen Fortministeriums betrachtet.*
The animal now is observed in/on a building of the vietnamese ministry of forestry.

    on   → three dimensional concept
    in   → three dimensional concept

Reference frames

- Levinson (1996) assumes a partition into intrinsic, relative and absolute reference frames

- Intrinsic frame:
  - binary relations (figure, ground)
  - the center of a coordinate system lies on the ground
  - needs distinguishable parts of the ground, so that front, back, top and bottom can be assigned

- Relative frame:
  - ternary relation (figure, ground, viewpoint)
 - viewpoint needs to be distinct from the ground

Reference frames

Levinson (1996):

- Example 1 and 2 are intrinsic

- Example 3 is relative

1. *The ball is in front of the chair.* (at the chair's front)

2. *The ball is in front of you.*

3. *The ball is in front of the tree.*

Intrinsic or relative frame

- For Levinson's first example, without the information added in parentheses, it is almost impossible to tell an intrinsic from a relative frame

- *The ball is in front of the chair.*
    - at the chair's front?
   - between the chair and me?

?
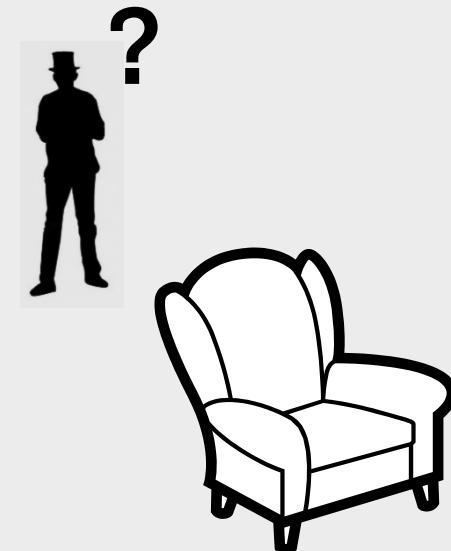
Intrinsic or relative frame

- The same is true for many sentences in which intrinsic sides can be assigned to an object

  Hinter der Kapelle zeigt Zita uns den Höhepunkt der Wanderung.

  'Behind the chapel Zita reveals the highlight of our hike to us.'
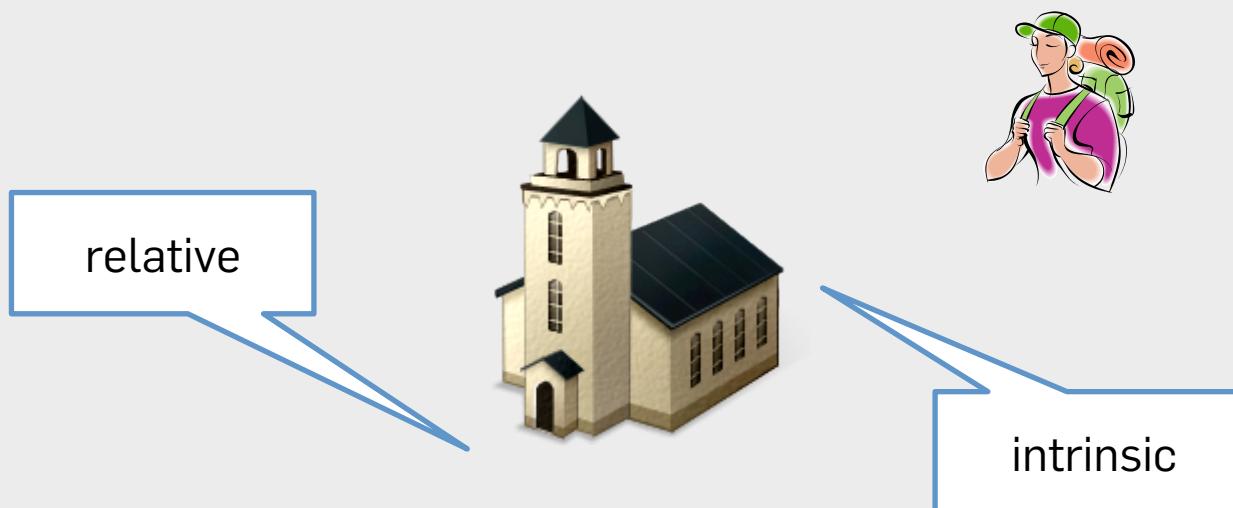
relative

intrinsic

Annotation of reference frames

- Without the knowledge about the spatial configuration it is often not possible to tell an intrinsic from a relative reference frame.

- Hence, it often is not possible to annotate the reference frame used.

- It is only possible to refer e.g. to region *in front of* or *behind* the reference object, but not if these had been assigned in relative or an intrinsic frame.

From annotation to other tasks

- For the purpose of annotation the level of specification of the BSDA is sufficient

- For other tasks it might be useful too add information about

  – The interaction of functional and geometric information
  – Object features that might influence the possible concepts and thus the preposition uses
  – The influence of reference frames

- The feature description of the BSDA can be seen as a geometrical basis that can enriched with additional features

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Thank you very much for your attention!