Lexikalische Semantik— Elemente eines DRT-basierten Lexikons HS

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1 A part of the conceptual background theory, concerned with time, space and motion

1.1 Time as a Newtonian-Kantian Category

The basic conception of time as it is manifest in human language and cognition is that of an ordered medium. We will assume that this medium is conceived as *absolute* (in the sense of Newton as against Leibniz) and as linear in both directions (the direction of the future as well as that of the past). [1] We will assume therefore that time consists of a linear ordered medium $\langle$ T,$\prec$ $\rangle$, consisting of a set T of temporal instants and an 'earlier-later' relation $\prec$ between them. Linearity of the relation $\prec$ can be secured by means of the following axioms:

[1] It is often contended that time is not linear in the direction of the future inasmuch the future is 'open': while things could not have been as they actually were, the future can still develop in more than one way; partly the way it will go depends on our own decisions. Although we believe that this is true - at the very least it is a fundamental aspect of the way in which people view the future - we do not think that this is to be understood as a conceptual commitment to 'branching time', and thus to the non-linearity of time. Rather, the conception is better understood as involving a sheaf of possible futures, one of which will, given the way in which things will turn out, reveal itself as the real future. It is to the time of this continuation of the actual world into the future that we think as 'the future'. (In fact. for all we know the structure of time of other, possible but non-actual futures may be identical with the structure of time in the actual future, but this is an additional assumption, stronger than the assumption that in each possible world the order of time is linear, whihc leaves open the possibility that different worlds might determine distinct linear orders.)

I.1 $x \prec y \rightarrow \neg (y \prec x)$
I.2 $x \prec y \ \& \ y \prec z \rightarrow x \prec z$
I.3 $x = y \vee x \prec y \vee y \prec x$

In the everyday conceptualisation of time, periods play a crucial role as well. We will assume that all limited periods have temporal boundaries, which are instants from T. This means that each bounded interval can be represented by means of pair (t,t') of instants from T, with $t \prec t'$. The order-based relationship between periods is more complicated than the order relation between instants. We can distinguish between complete precedence $\ll$ ($(t_1,t'_1) \ll (t_2,t'_2)$ iff $t'_1 \prec t_2$), overlap $\bigcirc$ ($(t_1,t'_1) \bigcirc (t_2,t'_2)$ iff $t_1 \leq t_2 \leq t'_1 \leq t'_2$ or conversely), inclusion $\subseteq$ ($(t_1,t'_1) \subseteq (t_2,t'_2)$ iff $t_2 \leq t_1 \leq t'_1 \leq t'_2$), identity $=$ ($(t_1,t'_1) = (t_2,t'_2)$ iff $t_1 = t'_1$ & $t_2 = t'_2$), etc. There are a total of 13 mutually exclusive relations of this type, known as the 'Allen relations'.

The logical relations between the Allen relations (and others, such as inclusion, which isn't one of the Allen relations because $\subseteq$ is different from $=$, yet does not exclude it), can be derived from the definitions in terms of $\prec$. Alternatively one could take the periods of time and some or all of the Allen relations as primitive relations, with axioms capturing their logical properties directly, and then define the notion of an instant in terms of the basic notion of a period. (It is known that one can take the notion of a period and the relations of complete precedence $\ll$ and overlap $\bigcirc$ between periods as primitives. We can define instants as maximal sets of pairwise overlapping events and an ordering relation between them by:

(i) a set S of periods is an *instant* iff$_{def}$.

(a) for any two periods p, p' $\in$ S, p $\bigcirc$ p' and
(b) if p is such that for all p' $\in$ S p $\bigcirc$ p', then p $\in$ S.

(ii) $S \prec S'$ iff there are $p \in S$, $p' \in S'$ such that $p \ll p'$

On the basis of axioms which capture the properties which $\ll$ and $\bigcirc$ have when periods are identified with intervals (t,t'), and $\ll$ and $\bigcirc$ are defined as indicated, then $\prec$ can be shown to have the properties of a linear order. Moreover, the underlying periods can now be identified with pairs (S,S') of instants of the kind just defined, with $S \prec S'$.

The axioms for $\ll$ and $\bigcirc$ mentioned above are the fol.2)lowing:

P.1 $x \bigcirc x$
P.2 $x \bigcirc y \rightarrow y \bigcirc x$
P.3 $x \ll y \rightarrow \neg (y \ll x)$

P.4 $x \ll y \rightarrow \neg\, y \bigcirc x$
P.5 $(x \ll y \;\&\; y \bigcirc z \;\&\; z \ll u) \rightarrow x \ll u$
P.6 $x \bigcirc y \vee x \ll y \vee y \ll x$

We leave it open which temporal entities should be considered basic - the instants, the periods or both. We also leave open whether time should be assumed to have further properties, e.g. whether the temporal order should be assumed to be *dense* - between any two instants there is a third - or whether it is *order complete* - if an infinite set of instants has an upper bound then it has a smallest upper bound. We will return to these questions when we come to the conceptualisation of motion.

Besides the topological properties and relations of time, *metric* properties, which have to do with how long a period is or how far in time to instants or periods are removed from each other, are important too. All human beings have a sense of how long things last, something that they can assess in terms of the regularities of night and day, of their own heart beat or breathing and thousands of other 'regular' processes. In many cultures this basic intuition has been reinforced by more or less sophisticated calendars, which partition the intervals between regularly returning events (such as day break or the day of shortest length) in equal portions - weeks, days, hours, etc. Most calendars are fairly complex. This is true also of the Gregorian calendar, which, with small adjustments, is the one used by us. In addition we now dispose of a large variety of different 'clocks', devices for measuring the duration of periods, based on any one of a large number of mutually periodic physical processes. (The quartz watch was the first great technological breakthrough in the direction of cheap, miniaturised information processing.)

All that matters in this connection is that (i) we have a deeply ingrained sense of temporal duration; (ii) this manifests itself in our regular use of a number of calendar concepts such as days, months, years, etc,; and (iii) we measure time in terms of various *units* (such as days, hours, minutes, seconds, years, siderial years, etc. Any one of these units is convertible into any of the others, so we could dispense with all but one. But in actual practice the range of different units seems natural, and it would be awkward to reduce all of them to one.

An explicit axiomatisation of all the metrical and calendar knowledge that is available to a normal adult of the Western world is a tedious business. Details can be found in various places. See e.g. [Kamp/Schiehlen:2002].

We will need to distinguish time points and temporal intervals from each other and from ontological categories which we will introduce as we go along. We use the 1-place predicate 'TP' to describe the sort of temporal instants and 'TI' to describe the sort of temporal intervals. It will be convenient to treat the instants as intervals of a special kind (which is distinguished by the fact that beginning and end coincide. Also, we introduce the assumption that each bounded interval has both a lower bound and an upper bound and that all intervals with these same bounds coincide with it. In addition, intervals can be infinite in either or both directions. If they are, then they temporally include all intervals which are bounded in the direction in question. To express these general assumptions axiomatically we need two place predicates expressing relations between intervals and points, LB for 'lower bound' and UB for 'upper bound', and the relation $\subseteq$ of temporal inclusion. LB and UB are partial functions in their second arguments

TO.1 $TP(x) \rightarrow TI(x)$
TO.2 $(LB(x,y) \ \& \ UB(x,y)) \rightarrow (TI(x) \ \& \ TP(y))$
TO.3 $(LB(x,y) \ \& \ LB(x,z)) \rightarrow y = z$
TO.4 $(UB(x,y) \ \& \ UB(x,z)) \rightarrow y = z$
TO.5 $TP(x) \rightarrow (LB(x,x) \ \& \ UB(x,x))$
TO.6 $(\neg\ (\exists y)LB(x,y) \ \& \ \neg\ (\exists y)UB(x,y)) \rightarrow (\forall\ z)(TI(z) \rightarrow z \subseteq x)$
TO.7 $(\neg\ (\exists y)LB(x,y) \ \& \ UB(x,u)) \rightarrow (\forall z)((TI(z) \ \& \ UB(z,u) \rightarrow z \subseteq x)$
TO.8 $(\neg\ (\exists y)UB(x,y) \ \& \ LB(x,u)) \rightarrow (\forall z)((TI(z) \ \& \ LB(z,u) \rightarrow z \subseteq x)$
TO.9 $(\neg\ (\exists y)LB(x,y) \ \& \ UB(x,u)) \ \& \ \neg\ (\exists y)LB(z,y) \ \& \ UB(z,u)) \rightarrow x = z$
TO.10 $(\neg\ (\exists y)UB(x,y) \ \& \ LB(x,u)) \ \& \ \neg\ (\exists y)UB(z,y) \ \& \ LB(z,u)) \rightarrow x = z$
TO.11 $(LB(x,v) \ \& \ UB(x,u)) \ \& \ LB(z,v) \ \& \ UB(z,u)) \rightarrow x = z$.

N.B. 1. These axioms may become derivable from other axioms when a particular development of the systems of temporal instants and intervals is chosen (e.g. one which develops one category out of the other, along the lines briefly sketched above).

N.B. 2. Usually the sorts which we will introduce below will be disjoint from the sort of temporal intervals, as well as from each other. We will always need axioms which make these mutual exclusions explicit. Thus we need an axiom like GO.1 below to state that temporal intervals are distinct from spatial directions (using 'Dir' for the sort of directions).

GO.1 $TI(x) \rightarrow \neg\ Dir(x)$

('GO' stands for 'general ontology')

In the sequel we will not bother to state these exclusion axioms explicitly. Nevertheless, it should be kept in mind that with each new sortal predicate a whole batch of such axioms gets added to our axiomatic system.

1.2 Space

Our conception of space is different from that of time in several ways. First, it is not absolute in the way that time is. It is part of our conception of time that the temporal structure with which we are dealing is always the same. Even if the given context may focus our attention on a particular portion of time or suggest a certain granularity with which that part of time is considered, we are always dealing with the same, one-dimensional temporal ordering. The structures which function as our conceptions of space in different context vary more significantly. This is connected with the fact that conceptual space is not one- but three-dimensional.

As we saw in our discussion of PPS (primary perceptual space), one of the axes in terms of which space gets coordinated is always the same. This is the VERTICAL, a vector which points in the opposite direction of Gravity. With the VERTICAL comes what we will call the HRIZONTAL, a plane which is orthogonal to it. The two remaining axes that make up any given coordination must lie within this plane, but their choice will vary from context to context. We already saw that in a context in which an observer describes the position or the dimensions of an object that is at rest at some distance from him in a horizontal direction, the horizontal axes are (i) OBS, the axis which goes from the observer to the object, and (ii) TRANS, an axis which is perpendicular. The direction of this last axis is perhaps not intrinsic, but an orientation can be fixed through its relation to the other two (by the cork screw rule). It is this what fixes the directions RIGHT and LEFT in such a context: We can tell what is to the right of the observed object and what is to its left because these directions are fixed by what is 'up'(the direction in which our head is pointing when we are in a normal position) and the direction of observation OBS. We will assume here that TRANS has a direction and that it points towards the right.

There is a further respect in which context determines the coordination of PPS. Coordination does not only require a triple of mutually orthogonal vectors, it also requires an *origin*. In the simplest case of an observer describing an object at rest, it is the observer himself who provides the origin O. Exactly where O is to be located with respect to the observer's body - whether at his feet,in the center of his head, or in the middle between his eyes - may not be determinable, and in fact there is no need to cut the cake this finely. For simplicity we take O to be at the observer's feet. This choice means that VERT is the vector which starts at the observer's feet and points straight up. HOR will be the unique plane orthogonal to VERT which contains O, and HOR and TRANS with the orientations described above which equally begin at O.

In our discussion of position verbs and dimensional adjectives we also saw that many objects come with an intrinsic coordination of their own. This coordination could be partial or complete. First, objects come with a conceptualisation according to which they are either 1-, 2- or 3- dimensional. One-dimensional objects - pieces of rope, wire or thread, sticks, worms, the stripes on your pyjamas, etc. - always have an axis - this is just their one dimension. Note that we are here dealing with a slightly different notion of ‘axis’ since a fixed orientation is generally missing. (For some one-dimensional objects, such as walking sticks and (perhaps) worms, a direction is given by functional considerations, but in general there is no well-defined distinction between one end of the object and the other. We will continue our earlier practice of using the word vector for what has orientation as well as direction - so that VERT, OBS and TRANS are all vectors. We will use the word *axis* to refer to directions without orientation - to that, in other words which a given vector shares with the one which points in the opposite ‘direction’ (as the term goes [2]).

As we have seen, with two- and three-dimensional objects there may but need not be intrinsic axes. Two-dimensional objects which don’t have intrinsic axes are discs and square tiles, examples of two- dimensional objects which do are shelves and surf boards. Of course, when a 2-dimensional object has an intrinsic axis, then it automatically has two, the one given and a second which is perpendicular to it.

With 2-dimensional objects functional properties sometimes determine not just an axis, but a vector. (A surf board has a front end and a rear, some shelves have a front (which has been made to look nice) and an opposite (which has been left rough because it won’t show) or their front is determined by how they have been put into the book case or wardrobe of which they are part)

Three-dimensional objects were the category on which we spent most of our attention in our previous discussion of intrinsic axes and vectors. With such objects it is possible for coordination to be partial, as with a cylinder or a square tower without a clearly marked front.

A central assumption of our analysis of position verbs and of (our presentation of) Lang’s theory, s. [Lang:1989] of dimension adjectives was that we only considered objects whose intrinsic axes or vectors were parallel to one of the vectors of PPS. That is we have been working within a much simplified conception of spatial orientation, in which the only directional relations are

[2] Here, the terminology for which we have opted is at odds with ordinary parlance. In fact, when there is no danger of confusion, we will occasionally deviate form this terminological convention in the interest of more colloquial formulations

parallelism ($\|$) and orthogonality ($\perp$). This assumption (which is equally prominent in Lang's work) reflects a fundamental thesis, viz. that the limited system of geometry that is afforded by these two relations constitutes a cognitively and lexically important subsystem of a fuller conceptualisation of space in which there is full range of orientations. (That is: infinitely many orientations, instead of the total of 6 in the limited subsystem). We believe that this subsystem also plays an important role in connection with the conceptualisation of motion and its lexicalisations.

Given the importance of this principle, let us give it a name:

> (POSC) (= the Primacy of Orthogonality in Spatial Conceptualisation)
>
> Spatial orientations are perceived as much as possible in such a way that all relevant directions are parallel to one of the axes of PPS.

The way in which POSC manifests itself is our tendency to conceptualise directions that do not neatly fit the limitations of the limited subsystem of POSC as deviations from the norm that subsystem imposes. Thus a one dimensional object whose axis make not too large an angle with VERT will be conceived as an imperfect case of pointing up (and thus of standing), and when an observer is looking at a house from a position such that it doesn't present its front to the observer exactly at right angles to the direction of vision, he will try the case nevertheless as if the angle was 90^0.

To repeat, POSC should not be understood as implying that no other conceptualisation is possible. When intrinsic axes are at an angle of about 45^o with the axes of PPS, then acknowledging incompatibility with the possibilities of conceptualisation will become a virtual necessity. And besides there are lots of situations where even smaller deviations form the orthogonal norm are vital and where the richer, full conceptualisation of space is accordingly brought into play. Moreover, language readily follows suit in such cases by offering a vocabulary attuned to this richer set of spatial discriminations which the full conceptualisation makes available. But there is nevertheless an important distinction between this vocabulary and the lexicalisations (through verbs, adjectives and prepositions) with which we are primarily concerned here.

We begin our formalisation of the subsystem of POSC by just considering one type of spatial entities, viz. directions and the two relations between them which we admit, viz $\|$ and $\perp$. Let D be the set of directions.

D.0 $(\exists d)(\exists d') \neg d \parallel d'$
D.1 $d \parallel d$
D.2 $d \parallel d' \rightarrow d' \parallel d$
D.3 $d \parallel d' \,\&\, d' \parallel d'' \rightarrow d \parallel d''$
D.4 $\neg d \perp d$
D.5 $d \perp d' \rightarrow d' \perp d$
D.6 $d \parallel d' \,\&\, d' \perp d'' \rightarrow d \perp d''$
D.7 $d \parallel d' \rightarrow \neg d \perp d'$
D.8 $d \perp d' \rightarrow (\exists !d'')(d'' \perp d \,\&\, d'' \perp d')$
D.9 $d \parallel d' \text{ v } d \perp d'$

Of these axioms D.1 - D.7 are generally valid. D.8 reflects the Euclidean 3-dimensionality of space. ('$(\exists! d'')$' is the usual abbreviation for 'there exists exactly one'.). D.9 expresses the special limitations of POSC.

1.2.1 Thm

$\mathrm{Orth}(d_1,d_2,d_3) \,\&\, d \perp d_1 \,\&\, d \perp d_2 \rightarrow d \parallel d_3$

(Here '$\mathrm{Orth}(d_1,d_2,d_3)$' is short for '$d_1 \perp d_2 \,\&\, d_1 \perp d_3 \,\&\, d_2 \perp d_3$')

1.3

1.3.1

We now enlarge the ontology by introducing orientations, together with the notion of alignment, represented by the 2-place predicate Align. To be able to distinguish orientations from directions we introduce the predicate Ori for the set of orientations and the predicate Dir for the set of directions. Alignment means that two orientations point in the same direction. So alignment entails parallelism, but not conversely. The axioms D.1- D.7 are now to be understood as pertaining to directions and orientations together. D.8 and D.9 hold for directions but not for orientations. So they will have to be restated as in D8' and D9'

D.8' $\mathrm{Dir}(d) \,\&\, \mathrm{Dir}(d') \,\&\, d \perp d' \rightarrow (\exists !\, d'')(\mathrm{Dir}(d'') \,\&\, d'' \perp d \,\&\, d'' \perp d')$
D.9' $\mathrm{Dir}(d) \,\&\, \mathrm{Dir}(d') \rightarrow (d \parallel d' \text{ v } d \perp d')$

Warning! Such extensions of structural properties of relation like $\parallel$ and $\perp$ will be necessary repeatedly as we extend our ontology further. Thus they will also apply to lines, vectors and line segments. We will not always be explicit in this first introduction about these extensions. In the final version of the entire axiomatic theory they will be made fully explicit.

O.1 Align(o,o') $\rightarrow$ Ori(o) & Ori(o')
O.2 Ori(o) $\rightarrow$ Align(o,o)
O.3 Align(o,o') $\rightarrow$ Align(o',o)
O.4 Align(o,o') $\rightarrow$ o $\|$ o'
O.5 (Ori(o) & Ori(o') & Ori(o") & o $\|$ o' & o $\|$ o" & $\neg$ Align(o,o') & $\neg$ Align(o,o")) $\rightarrow$ Align(o',o")
O.6 Ori(o) $\rightarrow$ ($\exists$! d)(Dir(d) & d $\|$ o)
O.7 Dir(d) $\rightarrow$ ($\exists$o)($\exists$ o')(Ori(o) & Ori(o') & o $\|$ d & o' $\|$ d & $\neg$ Align(o,o') & ($\forall$ o") (o" $\|$ d $\rightarrow$ (o" = o $\vee$ o" = o'))

1.4 Points, lines and vectors

Next we introduce *points*, *lines* and *vectors*. The idea is that for each direction d and each point p there is a line l parallel to d going through p and, similarly, for each orientation o and each point p there is a vector v aligned with o and going through p. Conversely for each line there is a parallel direction and for each vector an aligned orientation. Parallel lines which go through the same point p are identical, and so are aligned vectors going through p. We introduce the predicates Poi, Lin and Vec for these three new categories, together with a predicate Inc which holds between (i) points and (ii) lines or vectors. Finally, we add the intuitive assumption that if two lines or vectors are parallel, then they have no point in common. All this is stated in the following axioms. First, we need to extend the relevant axioms about $\|$ and $\perp$ to lines and vectors. That is, D.1 - D.7 now hold for the union of the sets Dir, Ori, Lin and Vec. Also, the relevant axioms for Align, O.1 - O.4, are now adopted for the union of Ori and Vec. This means that everywhere in these axioms 'Ori' is to be replaced by 'Ori v Vec'. Thus O.1 now becomes:

O'.1 Align(x,x') $\rightarrow$ ((Ori(x) v Vec(x) & (Ori(x') v Vec(x')))

Moreover we need the following new axioms:

P.1 Inc(p,x) $\rightarrow$ Poi(p) & (Lin(x) v Vec(x))
P.2 Dir(d) & Poi(p) $\rightarrow$ ($\exists$ l)(Lin(l) & Inc(p,l) & l $\|$ d)
P.3 Ori(o) & Poi(p) $\rightarrow$ ($\exists$ v)(Vec(v) & Inc(p,v) & Align(v,o))
P.4 Lin(l) $\rightarrow$ ($\exists$ d)(Dir(d)) & d $\|$ l)
P.5 Vec(v) $\rightarrow$ ($\exists$ o)(Ori(o)) & Align(o,v))
P.6 Inc(p,l) & Inc(p,l') & l $\|$ l' $\rightarrow$ l = l'
P.7 Inc(p,v) & Inc(p,v') & Align(v,v') $\rightarrow$ v = v'
P.8 (Lin(x) v Vec(x)) & (Lin(x') v Vec(x')) & x $\|$ x' $\rightarrow$ $\neg$ ($\exists$ p)(Poi(p) & Inc(p,x) & Inc(p,x'))

The concepts of direction and orientation are often treated as abstractions in the sense that any two parallel directions are identical, and likewise any two aligned orientations. If we adopt these principles, then we can derive that there are at most 3 directions and at most 6 orientations.

A.1 Dir(d) & Dir(d') & d $\|$ d' $\rightarrow$ d = d'
A.2 Ori(o) & Ori(o') & Align(o,o') $\rightarrow$ o = o'

Exercise: Show from the axioms given that the number of distinct directions is less than or equal than 3 and the number of distinct orientations is less than or equal to 6.

To make sure that the total number of directions is exactly three and the number of orientations is exactly six, we need to make sure that there are enough 'dimensions'. This is guaranteed by the following existence axiom for PPS:

PPS
Vec(VERT) & Vec(OBS) & Vec(TRANS) & Poi(O) &
VERT$\perp$ OBS & VERT$\perp$ TRANS & OBS$\perp$ TRANS & Inc(O,VERT) & Inc(O,OBS) & Inc(O,TRANS)

We saw that it is an important feature of PPS that the VERT is always given and with it the notion of a plane perpendicular to it, the HORIZONTAL. Here too it would be natural to distinguish between the abstract concept of such a plane and the idea of a particular plane which intersects VERT at some particular point, just as we have distinguished between directions and lines and between orientations and vectors. However, we will make a little saving on notions at this point by only introducing the concrete planes. We introduce the predicate Pla for this purpose. For the time being the assumptions we make about planes are

(i) that each plane contains at least one line and, moreover, will contain for each line it contains also a line orthogonal to that line; and

(ii) that there is a relation of orthogonality between planes and lines, with the properties that

(a) two lines that are orthogonal to the same plane are parallel, and

(b) two planes that are orthogonal to the same line are parallel (in that they do not contain a common line);

Finally we assume that

(iii) through each line l and point p on l there is a plane which contains p and is orthogonal to l.

Note that (iii) entails among other things that for each point p on VERT there is a plane containing p and orthogonal to VERT.

We use the predicate 'Con' for the containment relation between planes and lines/vectors, and extend the use of the symbol $\perp$ to describe the relation of orthogonality between planes on the one hand and directions, orientations, lines and vectors on the other. We also extend the use of Inc to include the case where a point lies in a plane.

Special care is needed in connection with parallelism. Planes can be parallel to each other just like lines and their ilk can be. And within the domain of planes parallelism is an equivalence relation and it excludes $\perp$. so far so good. But there is a problem when it comes to parallelism between planes and lines. A plane f can be parallel to two lines l and l' without this entailing that l is parallel to l'. The simplest way to get out of this difficulty is to extend the range of $\|$ to include cases where the two arguments are both planes and to introduce a new predicate for the parallelism relation between planes and lines, for which we introduce the predicate '$\|$p,l'. In this way we can retain the structural properties of ($\|$,$\perp$).

We will state separately the property of planes which is analogous to P8: two parallel planes do not have a point in common. Moreover we assume that if a plane f and a line l are parallel, then there is a plane f' containing l which is parallel to f. To infer from this that no plane shares a point with any line parallel to it, we need also the intuitively trivial principle that if a plane f contains a line l and a point p lies on l, then it also lies in f. And. lastly, we want the principle that if two planes are not parallel then they have a line in common.

Pl.1 $\mathrm{Pla(f)} \rightarrow ((\exists\, \mathrm{l})(\mathrm{Lin(l)}\ \&\ \mathrm{Con(f,l)})\ \&\ (\forall \mathrm{l})(\mathrm{Lin(l)}\ \&\ \mathrm{Con(f,l)} \rightarrow (\exists\, \mathrm{l'})(\mathrm{Lin(l')}\ \&\ \mathrm{Con(f,l')})\ \&\ \mathrm{l'} \perp \mathrm{l})))$

Pl.2 $(\mathrm{Pla(f)}\ \&\ \mathrm{Lin(l)}\ \&\ \mathrm{f} \perp \mathrm{l}\ \&\ \mathrm{Lin(l')}\ \&\ \mathrm{f} \perp \mathrm{l'}) \rightarrow \mathrm{l} \parallel \mathrm{l'}$

Pl.3 $(\mathrm{Lin(l)}\ \&\ \mathrm{Pla(f)}\ \&\ \mathrm{f} \perp \mathrm{l}\ \&\ \mathrm{Pla(f')}\ \&\ \mathrm{f'} \perp \mathrm{l}\ \&\ \mathrm{f} \neq \mathrm{f'}\ ) \rightarrow \neg\ (\ \exists\, \mathrm{l'})(\mathrm{Lin(l')}\ \&\ \mathrm{Con(f,l')}\ \&\ \mathrm{Con(f',l')})$

Pl.4 $\mathrm{Poi(p)} \rightarrow (\exists\, \mathrm{f})(\mathrm{Pla(f)}\ \&\ \mathrm{Inc(p,f)}\ \&\ \mathrm{f} \perp \mathrm{VERT})$

Pl.5 (Pla(f) & Pla(f') & f $\|$ f' & f $\neq$ f') $\rightarrow \neg$ ($\exists$ p)(Poi(p) & Inc(p,f) & Inc(p,f'))
Pl.6 (Pla(f) & Lin(l) & f $\|$f,l l) $\rightarrow$ ($\exists$!f')(Pla(f') & Con(f,l) & f' $\|$ f)
Pl.7 (Pla(f) & Lin(l) & Poi(p) & Con(f,l) & Inc(p,l))$\rightarrow$ Inc(p,f)
Pl.8 (Pla(f) & Pla(f') & $\neg$ (f $\|$ f')))$\rightarrow \neg$ ($\exists$ l)(Lin(l) & Con(f,l) & Con(f',l))

Of particular conceptual importance is the *horizontal plane*. However, as it stands 'the horizontal plane' is a misuse of the terms introduced. For there isn't just one horizontal plane, but as many as there are distinct points on any line parallel to VERT. In order to be able to speak of 'the horizontal', we must introduce a spatial category which stands to planes in the same way that directions stand to lines. We haven't been able to find a good word for this category. We propose, for lack of something more pleasing, 'plane direction', and use the predicate 'Pld' to represent it in our formalisation. The axioms which link this notion to those already introduced resemble the earlier ones for lines and directions.

Pld.1 Pla(f) $\rightarrow$ ($\exists$ g)(Pld(g) & g $\|$ f)

Pld.2 (Pld(g) & Poi(p))$\rightarrow$ ($\exists$!f)(Pla(f) & INC(p,f) & f $\|$ g)

Pld.3 (Pld(g) & Pld(h))$\rightarrow$ g = h

We can now speak of the unique plane direction orthogonal to VERT. We will refer to it as the Horizontal ad use the individual constant HOR to denote it. Its fundamental properties - that of being a plane direction and of being orthogonal to VERT - are given in 'HOR'.

HOR. Pld(HOR) & HOR $\perp$ VERT

In connection with PPS there is also a particular plane parallel to HOR which is important. This is the plane going through the Origin of PPS. we call it 'GROUND' and use the individual constant GRO. Evidently, it will contain the axes OBS and TRANS.

GRO. Pla(GRO) & GRO $\|$ HOR & INC(O,GRO)

As a check on our axioms it should be verifiable that the following is now derivable:

Con(HOR, OBS) & Con(HOR,TRANS)

For what will be needed in the next section we also need the notion of a *(finite)line segment* (Lis) and that of the *length* of a line segment. Line segments are determined by (i) a line and (ii) a pair of points on that line. We assume that each such combination determines a unique line segment. The easiest way to make this explicit is to introduce a 4-place predicate LS, which holds between a line two distinct points and a line segment. The corresponding axioms are obvious:

LS.1 LS(x,y,z,u) $\rightarrow$ (Lin(x) & Poi(y) & Poi(z) & y $\neq$ z & Lis(u))
LS.2 (Lin(x) & Poi(y) & Poi(z) & y $\neq$ z) $\rightarrow$ ($\exists$ u)(Lis(u) & LS(x,y,z,u) & ($\forall$v)(Lis(v) & LS(x,y,z,v) $\rightarrow$ v = u)))

1.4.1

Note that while we have now fixed the number of possible directions and orientations, we have only given lower bounds to the number of lines and vectors. This is because we said nothing about the number of points. So far we have only said that for each PPS there is a point O which serves as origin for its coordinate system. However, we will introduce further existence assumptions about points as part of the assumptions we will make about the next set of notions, those of a *material object*, of an *object boundary* and of a *spatial region.*

We need predicates to distinguish these sorts from those already introduced and from each other. To this end we introduce three 1-place predicates: MO for 'material object', OB for 'object boundary' and SR for 'spatial region'. That they define distinct sorts is given by the following list of axioms

First the notion of a (material) object We already noted that objects can be conceived as being of either 1, 2 or 3 dimensions. To formalise this distinction, we introduce three further 1-place predicates, '1-D', '2-D' and '3-D', with the obvious interpretations. The following axioms say that each material objects is conceived as either 1-, 2- or 3-dimensional, and that these three possibilities exclude each other.

MO. 1 MO(x) $\rightarrow$ (1-D(x) v 2-D(x) v 3-D(x))
MO. 2 (1-D(x) $\rightarrow \neg$ 2-D(x)) & (1-D(x) $\rightarrow \neg$ 2-D(x)) & (1-D(x) $\rightarrow \neg$ 3-D(x)) & 3-D(x)) & (2-D(x) $\rightarrow \neg$ 3-D(x))

It is important to stress that the distinction between 1—, 2— or 3-dimensionality is a matter of *conceptualisation within a certain type of context.* All material objects allow for a basic conception as three-dimensional

— to be a material object is to consist of matter, and matter implies extension in the sense that it must occupy a certain volume; and volume entails 3 dimensions. In fact, if it wasn't possible to think of a coin or a board — typical examples of objects which we tend to think of as two-dimensional for the sake of ascription of dimensional properties — as at the same time 3-dimensional as well, we couldn't conceive of them as standing on their side, but that is precisely one of the possible positions to which descriptions by means of dimensional adjectives can apply and in which their conception as 2-dimensional objects is therefore relevant. The predicates '1-D' and '2-D' are to be understood with this in mind. They do exclude '3-D', but do not assert that their arguments are three-dimensional in the sense in which every material object must be.

We already noted that some material objects come with intrinsic directions or orientations. These can either be determined by shape or by function. We assume that they can be described in terms of orthogonal coordinate systems that are in some way intrinsic to the objects. The axes of these coordinate systems are either mere directions (as we have called them), or they come with an orientation. The coordinate axes determined by geometrical shape are always mere directions, those determined by the object's function are usually orientations.

N.B. it appears to be a matter of decision whether to identify the axes of a coordinate system intrinsically related to a material object as directions/ orientations or as lines/vectors. We have adopted the former option here. The reason will become clear below.

We start with geometrically determined coordinate systems. To describe these we need five three 2-place predicates, 'MAX', 'MIN', 'INT'. Of these MAX and MIN only apply in addition to to directions; INT can apply also to planes. Finally, the second arguments of MAX, MIN, INT are always orthogonal to each other. This gives us as general axioms:

GD.1 (MAX(x,y) v MIN(x,y)) $\rightarrow$ (MO(x) & Dir(y))
GD.2 INT(x,y) $\rightarrow$ (MO(x) & (Dir(y) v Pla(y)))
GD.3 (MAX(x,y) & MIN(x,z)) $\rightarrow$ y $\perp$ z
GD.4 (MAX(x,y) & INT(x,z)) $\rightarrow$ y $\perp$ z
GD.5 (MIN(x,y) & INT(x,z)) $\rightarrow$ y $\perp$ z

i. 1-dimensional objects. As we have seen, a1-dimensional object always determines one axis, and this one qualifies as MAX:

GD.6 MO(x) & 1-D(x) $\rightarrow$ (($\exists$ d)MAX(x,d) & Dir(d)) & $\neg$ ($\exists$d')MIN(x,d') & $\neg$ ($\exists$d")(INT(x,d"))

ii. 2-dimensional objects. A 2-dimensional object may have an intrinsic axis. If it does, then there are always two, and one of them will play the role of MAX and the other that of MIN. A 2-dimensional object which does not have an intrinsic axis is taken to determine a plane (that in which, intuitively, the object lies).

GD.7 (MO(x) & 2-D(x) & ((∃y)(MAX(x,y) v MIN(x,y))) →
((∃d')MAX(x,d') & (d∃")(MIN(x,d") & ¬(∃y)(INT(x,y))

Also each 2-dimensional object determines a plane. We will assume that this plane is fully determined by the object at any particular time: the orientation of the object in PPS determines the plane's direction in PPS. Furthermore, the plane is assumed to go through any point belonging to the object (and it is assumed that with a 2-dimensional object all thes points lie in the same plane, so that it doesn't matter which point one chooses to identify the plane we want). We assume a 2-place predicate PL to express this: If y is 2-dimensional, then there is a plane y such that PL(x,y). Moreover, we assume that if x does not have an intrinsic coordination, then this plane acts as INT.

GD.8 PL(x, y) → Pla(y)
GD.9 (MO(x) & 2-D(x)) → (∃y)(PL(x,y) & (¬ (∃ z)(MAX(x,z) →
INT(x,y)))

Summarising, from the present point of view 2-dimensional objects come in two categories, those for which MAX and MIN are defined and those for which they are not.

iii. 3-dimensional objects. With 3-dimensional objects there are three different cases to be considered in which we find something like a geometrically intrinsic coordinate system. The first case is exemplified by objects such as a typical brick, the surface of which consists of faces which are at right angles to each other and where the dimensions of the edges which bound the faces are clearly distinct. E.g. the dimensions of a brick might be 20 cm x 10 cm x 5 cm. Such an object x is conceived as determining three orthogonal axes, which are parallel to the different edges (of which there are twelve, representing three different directions between them). Once again the axes are distinguished by the lengths of the edges to which they are parallel. We denote the axis (i.e. direction) of the longest edges as MAX(x), the axis of the shortest edges as MIN(x) and the axis of the edges of intermediate size as INT(x).

The second type of 3-dimensional object is exemplified by a longish cylinder (such as a biscuit tin) or a tall speaker box with a square ground plan. (The assumption about these objects is that they are much taller than they are 'wide', e.g. the height of the cylinder should significantly exceed the radius of its cross section, and similarly for the box.) Here only one axis is intrinsically determined. With the cylinder it is what is usually called the axis of the cylinder (i.e. the direction which is perpendicular to the circular cross section of the cylinder), with the speaker box it is the direction of the longest edges. This axis is in both cases denoted as MAX(x). Apart from their intrinsically determined axes MAX(x) all that these objects give us is a plane perpendicular to this axis - the plane of the ground plan in the case of the speaker box and that of the circular cross section in the case of the tin. This plane is denoted as INT(x).

The third type is very much like the second except that now the one intrinsically determined axis is shorter, not longer, than the dimensions of the cross section to which it is perpendicular. Typical examples are a coin, or a tile that is, say, square or hexagonal in shape. (Such objects can normally also be conceived as 2-dimensional, but the possibility of conceiving them as 3-dimensional, where their 'thickness' becomes part of the conceptualisation, exists as well. It is from this second perspective that they are being considered here.) In this case we describe the intrinsic axis as MIN(x), while the plane perpendicular to it is once more described as INT(x).

Note that the second and third types of 3-dimensional objects can be seen as partially determining a coordinate system: One axis is fixed, but in the plane perpendicular to it two orthogonal axes can still be chosen more or less *ad libitum.* Only such a choice will complete the coordinate system.

Besides these 3-dimensional objects, which determine full or partial coordinate systems, there are also those which do not single out any direction. The paradigm of this case is any object in the shape of a ball, like a football or an orange. Another type of example is constituted by objects that are the shape of a cube, e.g. a die. Here any direction is as good as any other. For such objects x MAX, MIN and INT are all undefined.

In this classification we have restricted attention to objects of quite special shapes. Such shapes are of course idealisations, some objects fit them very closely, others reasonably well and there are also many which have to undergo some procrustean adjustments before they can be regarded as legitimate representatives of the paradigm. We believe that this concentration on idealised 'Gestalts' reflects an important aspect of human cognition - that when it comes to describing objects with the use of certain terms the observer forces them into one of these spatial schemata if that is at all possible, even if they are perfectly capable of perceiving all sorts of ways in which the object deviates from the chosen schema (e.g. in connection with how to pick it up, put it down, fit it into a given space etc.) An example in point are objects of an elliptical shape (e.g. an old-fashioned snuff box). If the dimensions of such an object cooperate, then it will be conceived according to the schema of the brick, with a fully determined coordinate system, two axis of which are the axes (in the standard geometrical sense) of the elliptical cross section and the third perpendicular to them.

N.B. there are shapes which are not, we believe, conceptually reduced to those of the examples we have so far mentioned. As far as we can see most (and perhaps all) of these won't be describable in the special terms for which the framework that we are in the process of developing is intended to account. An example is a pyramid with square base. Pyramids fall outside our limited frame in which all angles are either 0^0 or 90^0, as the obliqueness of the sides of the pyramid is an essential part of the concept. Nevertheless some of the NL terms which the present framework wants to explain are applied also to objects the shape of pyramids, so a further extension of what is being developed here will be required at some point. The remainder of this remark is meant just as an indication of the complexities that are still in store for us.

It seems to us that objects which have the shape of pyramids are typically conceived as such, and not as distortions of some other Gestalt schema. And furthermore that it is part of this conception that the object comes with an intrinsically defined top (the vertex opposite the square face), and hence with an intrinsic axis, defined by the vector which goes through the top and is perpendicular to the square base, while pointing from the base to the top. If this is correct, then what we have here is a geometrically defined coordinate axis with an orientation as well as a direction. Besides this axis we only have the plane orthogonal to it (i.e. the plane of the square base).

The classification in terms of MAX, MIN, INT does not apply to pyramids, and we refrain from introducing additional notions into our representation language which would make it possible to include objects of this shape in our formal treatment of dimension descriptions which will be given below. In any case, the case of a four-sided pyramid was meant as just one example from a domain which we have not explored and of which we have no way of estimating either its size or the extent of its complexity.

Once more a summary. There are four categories of 3-dimensional objects: (i) those for which MAX, MIN and INT are all defined, (ii) those for which MAX and INT are defined, but MIN is not (and for which INT is a plane rather than a direction), (iii) those for which MIN and INT are defined, but MAX is not, and finally (iv) those for which none of these magnitudes are defined.

For 3-dimensional objects we follow Lang in sometimes using the notation (a(x), b(x), c(x)) to denote the three axes (MAX(x), INT(x), MIN(x)) in case all three are defined; (a(x), (b,c)(x)) for objects which have just MAX and INT, and (a,b)(x), c(x)) for those which have INT and MIN. Also for 2-dimensonal objects with MAX and MIN we write (a(x), c(x)). The single axis of a 1-dimensional object x will also be characterised as a(x).

Functional characterisations Many objects come with one of more functional orientations, which have to do with the natural position that the object should occupy in order to function in the way it is intended. On the one hand we find this with orgnisms. Human beings have three orientations, one pointing from the feet to the head, denoted by vert_{fun}(x) one pointing from the back to the chest, denoted as front_{fun}(x) and a third one, going from the left side of the person's body to its right side, this axis we denote as leftr_{fun}(x). The subscripts 'fun' will often be omitted. Arguably there are also 1— and 2—dimensional organisms, e.g. worms and flatfish. These two have functionally determined axes. For the (1-dimensional) worm the one axis is that which points from its tail to its head (we are assuming that this is well-defined), and for a flat fish there are two, one going from tail to head and one going from left to right (when the fish is right side up). We denote the first of these two as front_{fun} and the third as leftr_{fun}(x). An example of a 3-dimensional organism where there is only a partial determination is a tree. Here vert_{fun}(x) is defined, but no other axes.

Note that in all these cases we are e dealing with orientations and not just with directions. This is a general feature of functionally determined axes.

Equally common are functional axes for artefacts. An example of a 1-dimensional artefact with an orientation would be a walking stick (with a clearly marked knob at the top or a metal reinforcement at the bottom). Here vertfun(x) is the orientation pointing from bottom to top. A 2-dimensional artefact such a painting has (with marginal exceptions) an intended orientation (which makes it possible for instance to say of a painting that it is hanging upside down. The orientation going from the bottom to the top is again vert_{fun} (x). In addition there is a second axis going from left to right, denoted as leftr_{fun}(x).

For 3-dimensional objects there is sometimes a full, sometimes a partial functionally defined coordinate system. An example of the first is a wardrobe or a house, which have a functionally defined top as well as a functionally defined front. This makes wardrobes and houses, from the present perspective, like people. An example of a 3-dimensonal artefact with a partial functional coordinate system would be a tower, a bisquit tin or a dinner plate. Here only vert_{fun}(x) is defined. All such objects are like trees.

Many objects, including the majority of these which have just been mentioned, have geometrically determined directions as well as functionally determined orientations. Typically, and as assumed in the present conceptualisation, for any pair of a functionally and a geometrically determined direction the two will either be parallel or orthogonal. As we have seen, the use of the position verbs *liegen* and *stehen* is determined in part by these relations between the functional and geometrical axes of the object.

1.5 Regions of space.

The quasi-Newtonian container conception of time and space (the latter in the sense of PPS!) which has been adopted here naturally carries with it the idea that every material object occupies at any particular time a certain region of space. In principle it is possible - and sometimes it will be necessary - to refer to the region an object has occupied after it has moved to a different place. Moreover, the semantic analysis of locative and directional prepositions (such as German *in, neben, vor, hinter, über, ...,* either with Dative (locative) or Accusative (directional)) involves regions of space which need not be occupied by any material object. so we need regions of space. Just like material objects these come in three categories, 1-, 2- and 3-dimensional. (The domain of application of the predicates 1-D, 2-D and 3-D is accordingly extended.) We use the predicate Reg to refer to regions.

For the time being only three relations pertaining to regions will be relevant, that of a region being the one occupied by a material object or by some well-defined part of it, and the relations of spatial inclusion and spatial overlap. We use the predicates 'Occ', '$\subseteq$' and 'O' to denote these three relations. ('$\subseteq$' and 'O' are thereby extended from the temporal to the spatial domain, but with the understanding that these relations either hold between two entities which are both temporal intervals or two which are both regions of space. The structural properties of ($\subseteq$, $\bigcirc$) are transferred from the temporal to the spatial domain. These are: $\subseteq$ is reflexive, antisymmetric and transitive; $\bigcirc$ is reflexive and symmetric; and $\subseteq$ entails $\bigcirc$. (We won't bother now to state the axioms which make this explicit, but leave them as an exercise.) As far as the the relation Occ is concerned, we assume that the dimensionality of the material object is reflected in that of the region is occupies.

R.1 Reg(r)$\rightarrow$ (1-D(r) v 2-D(r) v 3-D(r))
R.2 MO(x)$\rightarrow$ ($\exists$! r)(Reg(r) & Occ(x,r))
R.3 Occ(x,r) $\rightarrow$ ((1-D(x) $\leftrightarrow$ 1-D(r)) & (2-D(x) $\leftrightarrow$ 2-D(r)) & (3-D(x) $\leftrightarrow$ 3-D(r)))

N.B. we may find the necessity later on to make further assumptions, e.g. that for any two overlapping regions there is a region which is included in both. We will introduce the corresponding axioms if and when required.

1.6 Boundaries of Objects and Regions

First, the notion of the surface of an object. Here we will distinguish between two closely related notions, (i) what we will call the surface of the object, and (ii) its skin. Surfaces are part of PPS (within which the object will occupy some particular region at any one time). The skin of an object is a material part of the object. So it moves with the object when the object moves, unlike its surface (in the somewhat technical sense in which that term is used here), which the object will 'leave behind' when it moves within PPS (except in the special situation of an object rotating with one of its symmetry axes as pivot. (cf. the rotation of a ball which remains in the same location during its rotation). At any time the surface of an object is the region which is occupied at that time by its skin.

We make the obvious assumption that both skins and surfaces are 2-dimensional. Further, we distinguish between the surfaces and skins of 3-dimensional objects and 2-dimensional objects. The skin of a 3-dimensional object has the topology of a sphere (i.e. it can be obtained from a sphere by a topological transformation); and the same is true of the surface of any 3-dimensional object. One consequence of this which is important for our concerns is that skins and surfaces have an inside and an outside, and that the only way to get from the outside to the inside or conversely, is to pass through the surface (i.e any line segment which goes through at least one point belonging to the outside and through at least one point belonging to the inside will have at least one point in common with the skin or surface. The object itself fills its skin completely, i.e. every point of the skin and every point inside the skin is a point of the object and conversely).

2-dimensional objects are conceived as being identical with their own skin. Thus the skin of a 2-dimensional object is also 2-dimensional and the same is true (as it should be; see R.3!) for the corresponding surface. The skins and surfaces of 2-dimensional objects differ topologically from those of 3-dimensional objects. Topologically the surface of a 2-dimensional object is what topologists call a disc: There is no distinction here between inside and outside; for any two points that do not lie on the skin or surface there is a curve connecting them which does not go through the surface.

We introduce 'Ball-like' and 'Disc-like' as predicates of 2-dimensional regions, and 'Ins' and 'Outs' as predicates which assign an inside region and an outside region to each 2-dimensional region s which satisfies 'Ball-like'.

These regions neither overlap with each other nor with s, and together the three exhaust all of space in the sense that any region which includes all of them will include any other region. Since each 3-dimensional object x will have a ball-like region for its surface, it determines an inside and an outside. We can approximate the statement that the region r it occpies is the 'sum] of its inside and its surface, by saying that r includes both and is included in every region that includes both.

> Disk-like surfaces do not have either an inside or an outside. Consequently, 2-dimensional objects don't either.

Sk.1 (MO(x) & (2-D(x) v 3-D(x))) $\rightarrow$ ($\exists$! y) Skin(y,x)
Sk.2 Skin(y,x) $\rightarrow$ (MO(x) & MO(y) & 2-D(y))
Sk.3 (Skin(y,x) & 2-D(x))$\rightarrow$ y = x
Sk.4 Surf(r,x) $\leftrightarrow$ ($\exists$! y) (Skin(y,x) & Occ(y,r))
Sk.5 (Surf(r,x) & 3-D(x)$\rightarrow$ Ball-like(r)
Sk.6 (Surf(r,x) & 2-D(x)$\rightarrow$ Disc-like(r)
Sk.7 Ball-like(s) $\rightarrow$ (($\exists$! r1)($\exists$! r2) (Ins(r1,s) & Outs(r2,s) & $\neg$ (r1 $\bigcirc$ r2) & $\neg$ (r1 $\bigcirc$ s) & $\neg$ (r2 $\bigcirc$s) & ($\forall$ r')($\forall$ r") ((Reg(r') Reg(r") & r1 $\subseteq$ r' & r2 $\subseteq$ r' & s $\subseteq$ r')$\rightarrow$ r" $\subseteq$ r'))
Sk.8 Disc-like(s) $\rightarrow$ ($\neg$ ($\exists$! r1)Ins(r1,s) & $\neg$ ($\exists$! r2) Outs(r2,s))

Bounded two-dimensional objects do not only have surfaces, but also a *contours*. In mathematical terms such a contour is a closed curve, a 1-dimensional region with the topology of a circle. Within any two-dimensional region which includes a given bounded region x, the contour of x defines an inside and an outside, in much the same way as the surfaces of three-dimensional objects. This will be relevant later especially for the case of flat regions x (i.e. regions x which are included in a plane). In addition to contours a 2-dimensional material object will also have a rim, which stands to its contour in the same relation as the skin of a 3-dimensional object to stands to its surface: The rim is a material part of the object and travels with it wherever it goes, whereas the contour stays behind. We will use 2-place predicates CONT and RIM to refer to the contour and rim of a 2-dimensional object. [Axioms follow later.]

> 1-dimensional objects do not have a skin or surface. Nor do they have a contour or rim.

What is true of 3-, and 2-dimensional material objects is partly true of bounded 3- and 2-dimensional regions of space. They too have surfaces and contours, though, of course, being immaterial themselves they do not have skins or rims. The axioms for the surfaces and contours of regions are in essence like those for the surfaces and contours of objects, (except that we now need axioms that associate surfaces and contours with the regions whose surfaces and contours they are, rather than specifying this via the skin or rim, as we have been doing for the surfaces and contours of material objects.) [Again, the axioms will have to wait.]

1.6.1 Edges, faces and vertices

Every 3-dimensional object, we saw, has a skin. For some 3-dimensional the skin can be further decomposed into parts which are separated from each other by 'edges'. Edges are line-segment-like entities which are part of the object's skin. Moreover, in many instances where an object has edges, the parts of the skin which are bound by those edges are of a special kind, called faces. This is true in particular for many of those objects which are paradigms of objects with geometrically determined coordinate systems, such as, for instance, a brick. Let us use the technical term block to refer to such objects. The faces of a block are always bounded parts of planes, and thus are flat. Each such face is bounded by two edges. Each of these edges will meet two other edges that bound the same face. The points at which two edges meet are called the vertices of the object. We assume that each of the vertices belongs to the skin of the object.

These decisions entail that we must be able to speak of the dimensionality of the parts of material objects: The concepts just introduced make it clear that 3-dimensional objects have besides 2-dimensional parts (skins and faces) also 1-dimensional parts (edges) and 0I-dimensional parts (vertices).

In order to be able to talk about the new concepts, we introduce the new 1-place predicate BLOCK, as well as three new 2-place predicates, VERTEX, EDGE and FACE. 'EDGE(y,x)' means that y is an edge of x, and likewise for 'FACE(y,x)' and 'VERTEX(y,x)'.

Our first axioms say that vertices of an object x are 0-dimensional parts of x; that for each vertex there exists a point which the vertex occupies; that edges of x are 1-dimensional parts of x; that faces of x are 2-dimensional parts of x; and that faces are flat - that is, a face occupies a 2-dimensional region which is part of a plane. To express the last axiom we extend the use of the predicate Occ and that of the mereological part relation $\subseteq$.

VEF.1 VERTEX(y,x)$\rightarrow$ (0-D(y) & y $\subseteq$ x)
VEF.2 EDGE(y,x)$\rightarrow$ (1-D(y) & y $\subseteq$ x)
VEF.3 FACE(y,x)$\rightarrow$ (2-D(y) & y $\subseteq$ x & ($\exists$ f)(Pla(f) & y $\subseteq$ f))
VEF.4 VERTEX(y,x)$\rightarrow$ ($\exists$ p)(Poi(p) & Occ(y,p)))

VEF.5 EDGE(y,x)$\rightarrow$ ($\exists$ r)(1-D(r) & Occ(y,r)))
VEF.6 FACE(y,x)$\rightarrow$ ($\exists$ r)(2-D(r) & Occ(y,r)))

The next axioms describe a block as having a surface consisting of 6 faces, with each face bounded by 4 straight edges (i.e. by 4 edges which are line segments), each edge bounded by two vertices and each vertex the end point of two meeting edges.

VEF.7 (BLOCK(x) & EDGE(z,x))$\rightarrow$ ($\exists$ p)(p')(v)($\exists$ v')(Poi(p) & Poi(p') & VERTEX(v,x) & VERTEX(v',x) & Occ(v,p) & Occ(v',p') & Occ(z,[p,p']))
VEF.8 BLOCK(x)$\rightarrow$ (($\exists$ 6!y)FACE(y,x) & ($\forall$ r)($\forall$ s)((SKIN(s,x) & 0-D(r) & r $\subseteq$ s) $\rightarrow$ ($\exists$ y)FACE(y,x) & r $\subseteq$ y))
VEF.9 (BLOCK(x) & FACE(y,x)) $\rightarrow$ ($\exists$ 4!z)(EDGE(z,x) & RIM(z,y)) & ($\forall$ r)($\forall$ s)((RIM(s,y) & 0-D(r) & r $\subseteq$ s)$\rightarrow$ ($\exists$ y)(EDGE(z,x) & & RIM(z,y)& r $\subseteq$ y))
VEF.10 (BLOCK(x) & VERTEX(u,x))$\rightarrow$ ($\exists$ 2!z)(EDGE(z,x) & u $\subseteq$ z)

[Question: Can some of these facts be deduced from others together with the axioms given before?]

N.B. We saw that every material object must be conceivable as 3-dimensional in some way. And seen in this way, every object has a skin, those which we have discussed as coming with a 1- or 2-dimensional conceptualisation as well as those whose conceptualisation is as 3-dimensional. However, we are here concerned only with objects *under a given conceptualisation*. Dimensionality is part of this conceptualisation. And when an object is conceived as 1- or 2-dimensional, this means that one is abstracting away from, among other things, its skin. So for us the skin of x will be defined only if x conceived as 3-dimensional.

For the time being we will not do much with these new concepts. We confine ourselves to introducing some of the necessary predicates, but interesting axioms concerning them will not be given until later. The predicates we will introduce here are: (i) a 1-pl predicate SUR for the sort of 2-dimensional surfaces; (ii) a 2-pl predicate SKI which associates with each 3-dimensional object its skin. The skin always belongs to the sort defined by SUR. (We will also introduce predicates for the inside and the outside determined by a skin. But this involves the notion of a spatial region and will have to wait until 3. below.)

2 Entries for Adjectives, Degree Adjectives and Length Adjectives.

1 There is no uniform scheme for the lexical entries of adjectives. Some adjectives, such as last and alleged (*letzt* and *mutmaßlich*) are operators on predicates and must be represented as such. however, the vast majority are predicates of some kind, which express a predication of the sentence subject when they occur as complements to copulas, and predications of the referential argument of the governing noun when they occur in prenominal position. The entries for the latter will have the general form given in (1)

(1)

	adjective ?? x
Selectional Restrictions	
Application Conditions	
Semantic Representation	

Here, x is the referential argument of the adjectival predicate, i.e. the thing of which the adjective predicates something; the question marks to the right indicate that the adjective may have additional, non-referential arguments, as we find with related to or acquainted with. The 'Application Conditions' are a rubric which we have not yet encountered in our sample entries but which we will find we need for the dimension adjectives which are our target here (and which also belong to the general category of predicational adjectives).

2. Many predicational adjectives are degree adjectives. This shows in their being modifiable by adverbs such as very, quite, somewhat and the like (*sehr, etwas, ziemlich*, ..) and with some of them also by certain measure phrases, such as 20 cm. It has been argued, and by now more or less conclusively, that degree adjectives have an argument slot for the degree to which they apply to a given object. In other words, the adjective relates its referential argument x to a degree. In a sentence like (2)

(2) Der Stock ist 70 cm lang.

the relation is between the stick and a certain length (or 'quantity of length'), which is denoted by the phrase *70 cm.*) 70 cm is an example of a measure phrase. Measure phrases consist of (i) an number expression, which is used to refer to a real number, and (ii) a name for a unit of measurement. Units of measurement are associated with a certain magnitude, such as length, volume, temperature, weight, etc. Magnitudes are functions from certain kinds of entities (material objects, distances in space, temporal intervals, events) to certain quantities, functions which map each entity for which they are defined to the quantity which the given entity possesses (of the magnitude in question). Magnitudes can be measured, with greater or lesser precision or accuracy. For the magnitude that will be our concern here, length, there exists a variety of mutually consistent, extremely precise and reliable measurement procedures. For length more than for any other magnitude this makes it reasonable to adopt the idealisation that the entities which have length have quantifies of length that allow for unique mapping into the set of real numbers, once a 'size standard', or unit of measurement is chosen, which maps some particular entity onto the real number 1. For length, as for many other magnitudes, it is proved useful to make use of a range of different units of measurement (rather than a single one, which would be enough in principle). Units of measurement for the same magnitude come with conversion rates, determined by th numbers which they assign to any one entity. (e.g. 1 kilometer = 1000 meters = 100.000 cm). For our purposes it will be convenient to identify the quantities of a given magnitude with functions which map each unit of measurement for the given magnitude to the real number which measures the given quantity in terms of that unit. Thus, if we were to consider just the units 'cm' and 'm' as units of measurement for length, then some particular length (e.g. that of a certain metal bar, or of the distance between two points in space) would be identified with the function whose domain is cm,m and which maps each of these to the number representing the given length in terms of the given unit. For instance, the given length might be the function which maps the unit 'cm' to the number 175,7 and the unit 'm' to the number 1,757; in other terms, the length would be the set of pairs { <cm,175,7>, <m,1,757> }.

Certain adjectives which are associated with magnitudes in the sense that they act as predicates of entities by expressing more directly properties of the quantities which this magnitude assigns to the entity. It is part of the semantics of such adjectives which magnitude they are connected with - this is what distinguishes between e.g. *long, heavy, warm* (*lang*, *schwer*, *warm*), which are connected with length, weight and temperature, respectively. But for one and the same magnitude there is often more than one adjective. For instance, connected with weight we have heavy and its antonym light (*schwer* and *leicht*). Length is a magnitude of special importance to us, and moreover, the significance of quantities of length varies considerably between different kinds of contexts in which the issue of length may arise. It is probably for this reason that for length we find an unusually large set of different adjectives which are all associated with this one magnitude.

These are the so-called dimensional adjectives (Dimensionsadjektive) studied in detail by Lang: *lang, breit, dick, hoch, tief, weit,* (together with various antonyms, like *kurz, schmal, eng, flach*, which we will ignore for the time being).

These adjectives are exceptional among other things in that they allow for argument phrases denoting degrees, i.e. for measure phrases as arguments. Therefore, one of the matters which we will have to sort out in order to find an adequate way of representing. the sentences on which much of Lang's study concentrates - e.g. *Der Ziegelstein ist 24 cm lang, 11 cm breit und 7 cm dick.* (This matter, fortunately is not hard.) It also mens that the entries for dimensional adjectives will all have the form given in (3). (As usual, the parentheses around the degree argument phrase indicate that the argument is syntactically optional).)

(3)

adjective	(measure phrase)
x	d
Selectional Restrictions	
Application Conditions	
Semantic Representation:	

The Selectional Restrictions for dimensional adjectives vary. *lang* is exceptional in that it can be used in general for bounded 1-dimensional regions of space (such as, among them, line segments), and 1-dimensional objects occupying them. (In this respect, though not in all others, *long* is like *lang.*) In addition to 1-dimensional regions and objects, *lang* is also applicable to 2- and 3-dimensional regions and objects, though in these cases it is always in virtue of some line segment or segments associated with the object or region that lang is applicable to its overt argument: the argument satisfies the given predication insofar as the selected line segment does (or segments do). In this respect the other dimensional adjectives are like lang, even though they cannot be applied to 1-dimensional objects or regions (or, in a few cases, only in special contexts; cf. *weit*).

The real problem which the dimensional adjectives present is how the relevant line segment or segments associated with a 2- or 3-dimensional argument are determined. This is a notoriously complicated matter. as a first step in the direction of a solution we recall the following from our earlier discussion.

a Many 2-dimensional and 3-dimensional objects come with intrinsically determined axes. (Along any such axis the object will have a certain length, viz. the maximal length of any line segment parallel to the given axis whose end points are on the surface of the object.) These axes an be determined either by the intrinsic geometry of the object (e.g. block, cylinder), or by the object's function (book), or by an intrinsic orientation in space (tree); often the intrinsic orientation is also related to function (wardrobe, vase). Geometrically determined axes are always directions, functionally or orientationally determined axes are orientations.

b . There are (at least) three strategies for describing the dimensions of objects to which the Observer-Describer stands in a certain spatial relation. We have considered this problem so far only in connection with situations in which the object and the observer occupy a single horizontal plane, and will stick with this restriction for the time being. In such situations, we saw, the relation between object and observer determines a full coordination of *Primary Perceptual Space* (PPS). We will refer to the three strategies as Dimension Description Strategies, or DDs. For the individual strategies we (almost) adopt Lang's terminology: We have (i) the *Intrinsic Dimension Description Strategy* (IDDS), (ii) the *Orientational Dimension Description Strategy* (ODDS) and (iii) the *Perspectival Dimension Description Strategy* (PDDS). IDDS describes the object with adjectives determined solely by its intrinsic axes, ODDS and PDDS do so by taking the position of the object in PPS into account. The latter two differ in that PDS choses its adjectives exclusively in terms of the orientation of the line segments an adjective is used to describe in PPs. ODDS does this only with regard to the two directions that lie in the plane of the face of the object the observer can see, but uses a different strategy for the dimension of the object in the directions of the observer axis OBS.

Each of the DDSs defines, for any pair consisting of an object x with certain intrinsic properties and an observer O who stands in a given (horizontal) orientation relation to the object, a correlation of adjectives with the different dimensions of x. More precisely, for each DDS ?DDS, ?DDS(x,O) is a function which maps each of the three dimensions of the object x (identified in terms of being parallel to the coordinate axis determined by the relation between x and O) to the adjective A that is to be used to describe that dimension according to ?DDS.

Given these functions we can then formulate the application conditions and semantic representation for a dimension adjective A. In particular, the semantic representation is to say that given any observer O positioned somewhere in the same horizontal plane as x and any one of three DDSs, the adjective A predicates of x that g (the degree argument of A is equal to the length of that direction of x in that direction d such that ?DDS(x,O)(d) = A. More formally, the semantic representation of the entry for the adjective will be:

$$\lambda\ ?\mathrm{DDS}.\lambda\ \mathrm{O}.(\mathrm{length}((\mathrm{Td})(?\mathrm{DDS}(\mathrm{x},\mathrm{O})(\mathrm{d}) = \mathrm{A}) = \mathrm{g})$$

The application conditions - which state when the adjective can be used at all given the intrinsic properties of x, the position of O and the choice of DDS, simply amount to A being in the range of the function λ.?DDS(x,O)(d): If A is not in the range of this function, then A cannot be used to describe the given x in the context which O and the given choice of DDS provide. Formally:

$$\lambda ?\mathrm{DDS}.\lambda.\ \mathrm{O}\ (\exists\ \mathrm{d})(?\mathrm{DDS}(\mathrm{x},\mathrm{O})(\mathrm{d}) = \mathrm{A})$$

If we know the function ?DDS, then this will tell us which dimensional adjective is to be used to describe each of the dimensions of an object x with given intrinsic properties by an observer O in a given position vis-a-vis x who chooses this DDS. Conversely, the use of certain adjectives in the description of the dimensions of x, in combination with the specification of these dimensions (in particular, explicit numerical specifications, as in *20 cm lang*, etc.) should enable us to draw inferences about the intrinsic properties and/or about the way in which it is presents itself to the describer.

2.0.2

The real problem which the dimensional adjectives present is how the relevant line segment or segments associated with a 2- or 3-dimensional argument are determined. This is a notoriously complicated matter. As a first step in the direction of a solution we recall the following from our earlier discussion.

a Many 2-dimensional and 3-dimensional objects come with intrinsically determined axes. (Along any such axis the object will have a certain length, viz. the maximal length of any line segment parallel to the given axis whose end points are on the surface of the object.) These axes an be determined either by the intrinsic geometry of the object (e.g. block, cylinder), or by the object's function (book), or by an intrinsic orientation in space (tree); often the intrinsic orientation is also related to function (wardrobe, vase). Geometrically determined axes are always directions, functionally or orientationally determined axes are orientations.

b. There are (at least) four strategies for describing the dimensions of objects to which the Observer-Describer stands in a certain spatial relation. We have considered this problem so far only in connection with situations in which the object and the observer occupy a single horizontal plane, and will stick with this restriction for the time being. In such situations, we saw, the relation between object and observer determines a full coordination of Primary Perceptual Space (PPS). We will refer to the four strategies as Dimension Description Strategies, or DDSs. We have (i) the *Intrinsic Dimension Description Strategy* (IDDS), (ii) two *Orientational Dimension Description Strategies* , the *Horizontal Orientational Dimension Description Strategy* (HODDS) and the *Vertical Orientational Dimension Description Strategiy* (VODDS), and (iii) the *Perspectival Dimension Description Strategy* (PDDS).

Each of the DDSs defines, for any pair consisting of an object x with certain intrinsic properties and an observer O who stands in a given (horizontal) orientation relation to the object, a correlation of adjectives with the different dimensions of x. Informally speaking, the strategies differ as follows. IDDS describes the object with the help of adjectives that are determined solely by its intrinsic axes, while the other three strategies all take the current position of the object in PPS into account, making the choice of adjective to describe a dimension of the object dependent on the current orientation of that dimension within PPS. The three differ in precisely how they do this. PDDS provides adjectives for all three dimensions in terms of PPS orientation, for HODDS and VODDS this is so for only two dimensions out of three; with HODDS these form a vertical plane (facing the Observer when he looks at the object in a horizontal direction, and with VODDS they form the horizontal plane which faces an observer when he looks at the object from above.

Formally, each DDS ?DDS is a function which assigns adjectives to the three dimensions of an object x that are to be used by an observer O who describes x looking at it from a certain position. The combination of x and O determines a (particular coordination of) PPS, which we will denote as PPS(x,O). In general the choices which a given strategy ?DDS provides is a function of (i) the intrinsic properties of x, and (ii) PPS(x,O). We denote this function as ?DDS(x,O), with x doing double duty as it were, with one duty that of providing its intrinsic properties and the other that of determining, through its relation to O, a particular PPS.

Suppose that PPS is given and that the object is placed within it in one of the positions that our conceptualisation permits. This presupposes that each of the intrinsic axes and planes of x is parallel to some axis of PPS or to a plane determined by two of its axes. For instance, the three axes of a block-shaped object will each be parallel to one of the PPS axes VERT, OBS and TRANS. So in this case we have six different positions for x, depending on how the dimensions of the object line up with the PPS axes. Thus the longest axis max(x) can be parallel with (i) TRANS, (ii) OBS and (iii) VERT, and for each of these three possibilities there is a further binary option, concerning the remaining two dimensions of x. e.g. in case (i), the shortest axis min(x) could be either parallel with VERT or with OBS, etc. For a second example, consider an object the shape of a cylinder. Here there are three positional possibilities, given by the orientation of the intrinsic axis of x, which, once again, can be (i) $\|$ TRANS, (ii) $\|$ OBS and (iii) $\|$ VERT. The orientation of the plane of the cross sections of the cylinder in PPS (i.e. of the plane orthogonal to the cylinder's axis) is then automatically fixed as well. (In case (i) it is the plane spanned by OBS and VERT, and so forth.)

With objects that have functionally determined axes, such as a wardrobe, the question of how the object is positioned in PPS is a little more complicated, since orientation (in the technical sense in which the term is used here) now plays a role too. Thus a wardrobe can be put upside down. For a block without functionally determined dimensions (e.g a brick) the notion of being upside down doesn't make sense. When I rotate a brick over an angle of 180^0, then it will be in a position which in present terms, is indistinguishable from the starting position. With a wardrobe this is never so, irrespective in which direction the rotation is performed.

We have been talking about the 'dimensions' of an object x without saying clearly what we mean by this term. In fact, common usage of the word dimension does not seem to force a fully determined concept upon us as its denotation. The sense in which we want to use it here is one which involves both a direction and a length. In this respect dimensions are much like line segments. But they aren't quite, for as a rule there isn't any one particular line segment with which a certain dimension of an object x could be identified.

To say what we mean by the dimensions of an object x, let us assume that x occupies a certain position in space and that d is a given direction. then any line l parallel to d will intersect the surface of x in two places. The intersection points determine some line segment with a given length. Let Dim(x.d) be the length of the longest line segment thus determined. The dimensions of an object x are the lengths of x in certain directions which are singled out in some special way. With a block these are the directions of the block's edges, with an object the shape of a cylinder they are: (i) the axis of the cylinder and (ii) any direction within its (circular) cross-section, and so on. Note that the line segments determined by the intersection points of the surface of a block with lines parallel to one of the distinguished directions (i.e. the direction of one of the block's edges) will all have the same length. Thus there is no uniquely determined line segment in this case, but the dimension in this direction is well-defined.

An explicit definition of the different DDSs presupposes, we have seen, a characterisation of the relevant types of objects. Thus we must assume that there is a function DDT (for ‘Dimensional Description Type’) which assigns each object x its relevant type. DDT must play a part in particular in the lexical entries for the nouns which lexicalise the relevant features. This is true in particular for nouns whose instances have functonally determined intrinsic coordinations, such as Schrank, Buch, Grabstein, Truhe, Baum, Turm, etc. (More problematic is the mater of lexical specification for a noun such as Ziegelstein (brick). Is it an intrinsic feature of bricks that their dimensions in the three orthogonal directions are significantly different, unusual.) We adopt Lang’s notation for the different DDTs. For block-like 3-D objects this consists of a 2 x 3 matrix, with the geometrically determined selections in the top row and the functionally determined ones in the bottom row. Thus for a brick, which has only geometrically determined dimensions we get:

(4) $$\begin{array}{lll} < a\ , & b\ , & c > \\ <\emptyset\ , & \emptyset, & \emptyset> \end{array}$$

In addition we need to know that the object is not hollow. For then and only then, we assume, can the shortest dimension of the object be described as *dick*. We simply add this as an extra feature to the DDT of the object, either in the abridged form ‘¬hollow’, used below or in the standard predicate logic form ‘hollow(x)’. So the DDT for a prototypical brick is as in (5)

(5) $$\begin{array}{llll} < a\ , & b\ , & c > & \\ <\emptyset, & \emptyset, & \emptyset> & \neg\ \text{hollow} \end{array}$$

Smilarly for a block with a square diameter but where the third dimension ($\perp$ to the square cross-section) is longer than the edges of the cross-section, we get (6)

(6) $$\begin{array}{llll} < a\ , & (b\ , & c\ )> & \\ <\emptyset, & \emptyset, & \emptyset> & \text{-hollow} \end{array}$$

and for a square tile (=Ziegel) (7)

(7) $$\begin{array}{llll} <\ (a\ , & b)\ , & c\ )> & \\ <\emptyset, & \emptyset, & \emptyset> & \text{-hollow} \end{array}$$

Let us also look at three objects with functionally determined dimensions. The first is a wardrobe, where the height is greater than its horizontal dimensions, and the second a sideboard, which is like a wardrobe except that its height is in between its width and its depth. The third is a rectengular trash can (i.e. one with a rectengular cross section and where the dimensions of this cross-section are notably smaller than its height). For these we get (8), (9) and (10), respectively.

(8)	< a ,	b ,	c >	
	<vert,	trans,	obs >	hollow

(9)	< a ,	b,	c >	
	<vert,	trans,	obs >	+ hollow

	< a ,	b ,	c >	
(10)	<vert,	trans,	obs >	+ hollow
	obs			

Let us suppose that we have a complete definition of:

(a) which DDSs are applicable to which types of objects (i.e. for which x ?DDS(x,O) is defined);
and
(b) in case ?DDS(x,O) is defined, what this function is.

This definition, together with a way of determing the different kinds of objects to which the DDSs apply, gives us one way in which we can complete the lexical entries for dimensional adjectives: Under the adjective's Application Conditions we list the possible strategies which are applicable to the predication bearer x and have the given adjective in their range. And we use as semantic representation a formula which says that, given the kind of object x is, its position in PPS and the DDS chosen, the degree argument g of the adjective is the (uniquely determined) dimension D of x in the selected direction d which the given DDS maps onto the adjective. So we get as general form for the entry of such an adjective

(11)

	adjective	(measure- phrase)
	x	g
<u>Selectional Restrictions</u>	Material object(x) or spatial region(x)	quantity of length(g)

Application Conditions:
The set of pairs $\langle$?DDS,O $\rangle$ of a DDS ?DDS and an observer position O vis-avis x such that adjective occurs in the range of ?DDS(x,O):
$\{<$?DDS,O$>$: adjective $\in$ Ran(?DDS(x,O)) $\}$
Semantic Representation:
The propositional function which maps each of the pairs $<$?DDS,O$>$ onto true or false, depending whether the dimension Dim(d) such that ?DDS(x,O)(d) = adjective is equal to the degree argument g of adjective:
$\lambda<$?DDS, O$>$. Dim(x, (ι d)(?DDS(x,O)(d) = adjective)) = g

Note that in this form the lexical entry for a dimensional adjective is immediately usefull primarily for purposes of language generation: When an observer O wants to describe the dimensions of an object from the particular angle from which it is viewed and O chooses a certain strategy (which is compatible with the intrinsic features of the object and his given view point), then the definition of the chosen strategy (still to be specified below) will give him, when it is applied to the object in question and the PPS determined by the viewpoint, for each of the relevant dimensions of x the adjective that is to be used to describe that dimension.

In the context of interpretation, on the other hand, (11) does not seem to be in a directly usable form, even if in principle it tells the interpreter everything that he needs. More directly useful to him are rules which tell him, for any one adjective, which dimensions of the object (as it presents itself to him) it could be used to describe, and what a particular interpretation of the adjective, according to which it is taken to describe a certain dimension of the object in question, implies about the strategy which the describer has used, and therewith also about the possible interpretations of the other adjectives that occur in conjunction with the first one. In particular, the description chosen by the observer should, when combined with information about the kind of the described object (brick, book, tower, etc) in some cases allow for inferences concerning the position in which the object presents itself to the observer. (Our own limited experience suggests that people find it quite hard to draw such inferences. This might be an indication that the information about dimensional adjectives which is of our concern here is represented in the human lexicon in a primarily generation-oriented form.)

In the remainder of this section we define the different DDSs. Once these have been given, we thereby have given lexical entries for each of the adjectives we have been looking at here (at least, as regards their use in the descriptions of the dimensions of objects that allow for the schematisation we have been assuming): All that needs to be done is to substitute in (11) the particular adjective (*lang, hoch*, etc.) for the schematic designator Adjective.

In the next section we will formulate 'interpretation friendly' principles concerning the meaning and use of the dimension adjectives. These will be consequences ('theorems') of the entries given in this section.

2.0.3 Definition of the DDSs.

Definition of the DDSs.

Before we give the actual definitions we first state some general principles:

1. Every function ?DDS(x,O) is 1-1

   (No adjective may be used twice in a single dimension description.)

2. IDDS ignores the current position of x and a fortiori its relationship to O.

   (So IDDS(x,O) would be more properly written as IDDS(x); we keep the former notation just for reasons of uniformity.)

3. PDDS describes all dimensions of x in terms of their relations to PPS. Thus PDDS(x,O)(d) is specified only by whether d is parallel to VERT, to OBS or to TRANS.

4. HODDS and VODDS provide perspectival specifications for two of the three dimensions of x., while leaving the third dimension to be specified by intrinsic considerations.

   With HODDS the first two dimensions lie in the vertical face of x facing an Observer looking at x from a horizontal direction.

   With VODDS the first two dimensions lie in the horizontal face of x which faces an Observer who looks at x from above. (An additional constraint on VODDS is that the longest dimension of x must lie in this horizontal plane.)

5. Functional specifications always override both geometrical specifications and perspectival specifications. More precisely, when one dimension d of an object x is functionally distinguished in a certain way and the adjective corresponding to that way is A, then A may not be used to describe that or any other dimension of x on other grounds.

   The specification of functionally determine dimensions is rigid in the sense that each functional feature specifies a unique adjective once and for all. The specification is as follows:

(12) vert ⇒ *hoch*;
trans⇒ *breit*;
sub⇒ *dick*;
obs⇒ *tief.*

6. There is also a fixed assign of adjectives to the geometrical features MAX, MIN, INT (or - in the alternative Lang notation we have adopted in the lexical specifications of nouns such as Ziegelstein, etc. - a,b,c. It is:

(13) MAX/a⇒ *lang*;
INT/b⇒ *breit*;
MIN/c⇒ *dick*, provided the object has the feature -hollow, undefined otherwise.

As far as objects are concerned which are conceived as 3-D and as having three functionally or geometrically distinct dimensions, we are now in a position to define when a strategy is applicable to an object and, in case it is applicable, what adjectives it returns as values when applied to the different dimensions of the object. We begin by considering objects that are not animals. The adjectives used to describe the dimensions of organisms differ in some instances and will be considered below.

IDDS IDDS is applicable to all objects with three distinguishable dimensions. We distinguish three cases: (a) the dimensions are determined exclusively in geometrical terms (brick); (b) they are exclusively determined in functional terms (wardrobe, sideboard, book, tombstone, drawer); (c) one dimension is determined functionally and the other two are distinguished geometrically (mail tray, chocolate box).

For case (a) we get as values the adjectives specified in 6. for the geometrically determined features of the object.

(Note that according to 6. we don't get a complete assignment when an object with purely geometrically determined axes is conceived as hollow, for in that case there is no adjective for the shortest dimension c. It is not easy to test this prediction, as objects of the relevant kinds seem hard to come by. It is possible that this is a place where our proposals will have to be adjusted.)

For case (b) we get the adjectives that are specified in 5. for each of the object's functionally determined features.

For case (c) we get:

(i) the adjective specified in 5. for the functionally specified feature.

(In our current experience this is (almost?) always vert, and thus the corresponding adjective is *hoch*.)

(ii) The adjectives specified in 6. for the two remaining geometrically determined features.

PDDS This strategy is defined only for objects whose dimensions are geometrically but not functionally determined (brick, cf. Lang). The specifications are similar to those for objects with functionally determined intrinsic coordinations:: if d1, d2 and d3 are the dimensions of the object which are parallel to the axes VERT, TRANS and OBS (of the given PPS defined by x and O), respectively, then the corresponding adjectives are:

(14) d1⇒ *hoch*;
d2⇒ *breit*;
d3⇒ *tief*.

HODDS This strategy is applicable only when the following conditions are satisfied:

(i) the dimension of the object that is parallel to OBS is intrinsicically determined (either functionally or geometrically), and the feature distinguishing this dimension determines an adjective according to 5. or 6. (The last qualification is necessary because of our assumption that MIN⇒ dick presupposes -hollow.)

(ii) If a dimension d that is parallel to the face of the object which is facing O (i.e either d $\parallel$ VERT or d $\parallel$ TRANS), and d is intrinsically distinguished by a functional feature, then this feature must be 'consistent with the current orientation of the object', so that the functional feature and the perspectival characterization according to the object's current position (see PDDS) assign the same adjective. This boils down to the following:

a. If d $\parallel$ VERT and d is distinguished by a functional feature then this feature must be vert.

b. If d $\parallel$ TRANS and d is distinguished by a functional feature then this feature must be trans.

c. A further constraint on the applicability of HODDS is that the resulting assignment, according to the definition below, is 1-1. Some cases that have not yet been ruled out by a. and b. will fail because of this further constraint.

(Exercise: find examples of objects for which this is the case!)

When conditions a. and .b. are fulfilled, and pending fulfilment of condition c., HODDS(x,O) gives the following assignments. Let d1 $\parallel$ VERT, d2 $\parallel$ TRANS, d3 $\parallel$ OBS. Then

d1$\Rightarrow$ hoch;
d2$\Rightarrow$ breit;
d3$\Rightarrow$ Adj. where either
a. d3 is distinguished by an intrinsic functional feature f and f$\Rightarrow$ Adj according to 5, or
b. d3 is only distinguished by an intrinsic geometrical feature g and g $\Rightarrow$ Adj according to 6.

VODDS .

This strategy is applicable only to objects which have a dimension that is geometrically distinguished as MAX, and whose current position is such that the dimensions geometrically distinguished as MAX and INT are both horizontal. Moreover, these dimensions should not be determined by functionally intrinsic features.

In addition we have in this case the same constraint as for HODDS: the specified assignment must be 1-1.

If these conditions are fulfilled, then VODDS assigns the following adjectives. Let d1, d2, d3 be the dimensions of x characterised by. d1 = MAX(x), d2 = INT(x) and d3 $\parallel$ VERT. Then:

d1$\Rightarrow$ lang;
d2$\Rightarrow$ breit;
d3$\Rightarrow$ Adj. where for Adj. there exist one or two possibilities: either
a. Adj = hoch or
b. d3 is distinguished by an intrinsic functional feature f and
f$\Rightarrow$ Adj according to 5.

Note that this allows in principle for two adjectives to describe d3. Always available is *hoch*. And in the case where d3 is functionally distinguished by obs, then an alternative possibility is *tief*.

Tomb stones Lang ([ref. to table] mentions (assuming we read him correctly) one exception to the principle that the choice of a functionally determined dimensional adjective always has preference over one determined in some other way. (This principle, we saw, entails that for objects with complete functionally determined coordinate systems the only description strategy available is that which assigns adjectives according to (12); thus it ignores the current position of the object and, by implication, its spatial relation to the observer.) The exception concerns tomb stones. Tomb stones have, like books, functionally determined coordinate systems which are 'inscription-based': In a typical tomb stone there is just one side which bears an inscription. This is the tomb stone's front side. Moreover, the front side gets an intrinsic coordination from the inscription it bears, since descriptions define what is up and what is down, as well as what is left and what is right. (Actually just one of these specification would have sufficed.) There are still several types of tomb stones to be distinguished, first in terms of their dimensions, and second in terms of their canonical positions. The two 'Gestalt types' of tomb stones distinguished by Lang are those which can be represented as in (15) and (16):

$$(15)\quad \begin{array}{llll} < \mathrm{a}\ , & \mathrm{b}\ , & \mathrm{c} > & \\ < & & , & \text{-hollow}> \\ <\mathrm{vert} & , \mathrm{trans}, & \mathrm{sub} > & \end{array}$$

$$(16)\quad \begin{array}{llll} < \mathrm{a} & , \mathrm{b} & , \mathrm{c} & > \\ < & & & , \text{-hollow}> \\ < \mathrm{trans}, & \mathrm{vert}, & \mathrm{sub} > & \end{array}$$

In addition, there probably also exist square tomb stones, which could be represented as in (17), though in our own experience such stones are fairly rare and we would be inclined to argue that they are untypical.

$$(17)\quad \begin{array}{llll} < (\mathrm{a} & , \mathrm{b}\ ) & , \mathrm{c} > & \\ < & & & , \text{-hollow}> \\ <\mathrm{vert} & , \mathrm{trans} & , \mathrm{sub} > & \end{array}$$

(For the use of parentheses see below).)

The canonical position of a tomb stone can be upright or else lying flat, either on top of the grave, or embedded in the ground. (The 'Forest Lawn' design!) For each of these cases the other position will be perceived as non-canonical: A tomb stone that is meant to be up right can have fallen over, or it can be lying, waiting to be put up right on the grave for which it is intended. Similarly, a tomb stone which is intended to mark the tomb for which it has been cut in a lying position may stand upright in the stone cutter's yard or in the cemetary before it is properly installed.

As a matter of fact it does not seem to matter very much whether the current position which the stone is to be regarded as its canonical one or not. In either case we find that there are no options for describing the stone's vert dimension when the stone is standing; in that case the only adjective that can be used to describe this dimension is *hoch*. But when the stone is lying, then - and it is here that we encounter the deviation from what has been stipulated in our definition of the DDSs above - we can describe this dimension not only with the help of hoch but also with that of lang.

The case is intriguing insofar as it requires us to make a further distinction that is important in connection with objects with functionally determined dimensions. We have seen in our discussion of the position verbs *liegen* and *stehen* that under certain conditions the observer can abstract form the object's function, and thereby avail himself of options which would not have been available otherwise. (Our example was that of a Teller (plate) which *steht* on the table that has been set for dinner, but liegt on the floor, wher it occupies a place which has nothing to do with its function, and where presumably it should not be.) Such an abstraction from the object's functional dimension determinations seems to be possible also in the case of tomb stones. This makes the tomb stone into something that behaves - as far as dimension descriptions go - like a brick. In the case where the tomb stone is viewed from above (which would naturally be if it was lying flat, whether or not that is perceived to be its canonical position), then VODDS would assign it the dimensional adjectives given in (18), provided its shape is as in (15) or (16):

(18) a $\Rightarrow$ l*lang*; b $\Rightarrow$ *breit*; c $\Rightarrow$ *hoch/dick*.

Moreover, the first of the two possibilities in (18) is also assigned by HODDS, though we suspect that this is not a very likely strategy to be applied to lying tomb stones.

As this discussion shows, the descriptions which —if we read Lang correctly – he maintains are available for lying tomb stones (those given in (15)) could be the result of a number of distinct strategies (involving choice of a DDS and possibly abstracting from the object's functional determinations) , and we do not know at this point which of those possibilities should be held responsible for the descriptive options which apparently exist.

We have dwelt on this case not so much out of an excessive interest in tomb stones, but because it is a case that according to the data mentioned by Lang seems to behave in a more complicated way than our fairly streamlined definitions of the DDSs allow for, and at the same time as a warning that expceptions to the possibilities which our DSs specify may well arise also in connection with other types of objects than those which we have so far managed to consider.

Next we turn to 3-D objects where only one dimension is distinguished (either functionally or geometrically or both).[3] We consider three cases, represented in Lang-notation as (i) <a,(b,c)>, (ii) <(a,b),c>, and (iii) <(a,b,c)>, respectively. (Recall: <a,(b,c)> represents the schema of a 'generalised cylindrical' [4] object in which one dimension, a, is longer than any dimension lying within the cross section perpendicular to this two while there is no significant difference in size between the dimensions that lie within this cross section; <(a,b),c> represents the schema of a rectangular object in which one dimension, c, is shorter than those lying in the perpendicular cross section while there is no significant difference in size between those; and <(a,b,c)> represents the schema of an object in which all dimensions are of the same size (e.g. a cube or a ball).

On our understanding of Lang's use of the notational scheme instantiated by (i), (ii) and (iii) above, they are meant to apply not only to objects that have six orthogonal faces (which is what we have been assuming up to this point) but also to objects that are conceptualised as cylinders, with one distinguished 'main' axis, while the cross sections of the object perpendicular to that axis are 'regular' 2-dimensional figures of a large variety. One such regular figure is a square, and objects of types (i) and (ii) with that kind of cross section fall within the purview of our earlier discussions insofar as they are the shape of blocks. But there are many other possibilities for the regular cross-section as well: a regular triangle, a regular petagon, a regular hexagon, etc. and, in the limit, a circle.

The case where the cross section is a square, however, is special in that this seems to be the only cross section shape where objects falling under the schemata (i), (ii) and (iii) above can receive a 3-dimensional description (i.e. one of the form 'x units A1, y units A2 and z units A3')

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[3]When an object has a complete functionally determined coordinate system, then the functionally determined specifications given in (5) apply also when its shape is like in (i), (ii), (iii) above. (For instance, a ward robe whose dimensions are, say, 180cm x 65 cm x 65 cm will be described as: *180 cm hoch, 65 cm breit und (ebenfalls) 65 cm tief.* As we will see below this is different for organisms.

[4]By a generalised cylindrical shape we understand a 3-dimensional shape which has one main axis and for which the cross sections perpendicular to that axis are regular two dimensional figures i.e. either a circle (this is the case of an actual cylinder), an equilateral triangle, a square or a regular polygon with 5 or more sides. (Strictly speaking the notion ought to be extended so that it covers additional cross-section shapes, e.g. by allowing cross sections which are like regular polygons except that the sides are not straight but slightly convex or concave. Wee won't bother with these subtleties here. however.)

In fact, block-shaped objects satisfying the three schemata (i), (ii), (iii) behave to some extent like objects with three distinguishable orthogonal dimensions. The only difference is that the adjective dick cannot be used to characterise any of the dimensions of an object satisfying schema <a, (b,c)> and lang cannot be used to describe any dimension of an object satisfying <(a,b) ,c)>. In the first case the reason is that ithe principle governing the use of dick is that it should to be used to describe the shortest dimension, but there is no such dimension in this case. (There are only dimensions that are among the shortest!) The same consideration blocks the use of lang in relation to objects satisfying <(a,b) ,c)>.

This restriction entails that objects in which there is no functional determination of any axis and which satisfy either schema (i) or schema (ii) are not within the scope of IDDS, as the adjectives *dick* (in the case of such objects satisfying (i)) and lang (in the case of those satisfying (ii)) are not available. On the other hand both these types of objects are amenable to PDDS. This is also true, moreover, of objects of shape <(a,b,c)>. Moreover, HODDS and/or VODDS can be applied to certain positions (vis-a-vis O), others being excluded because of the restrictions mentioned above.

> Exercise: Determine which positions of objects satisfying the schemata (i), (ii), (iii), respectively, allow for application of HODDS and/or VODDS according to what has been said here, and compare these results with your own judgements.

For objects satisfying the schemes (i) and (ii) for which the cross section is not a square, dimensional description takes a different form, involving at most two clauses instead of three. For instance, a round tower would be described as, say,

(19) 20 Meter hoch und 7 Meter dick.

Such descriptions leave us uncertain whether the conception that gives rise to them should be regarded as that of a 3-D or of a 2-D object. What we are seeing here is surely something different from the 2-dimensional conception that we have of such objects as floor boards, bill boards, blackboards, pictures, mirrors, walls, curtains or skins. The obvious difference is that the clause *7 Meter dick* in (19) is understood as the dimension along just any one of the many possible coordinate axes for the tower's cross section'. Compare this with the description of a board given in (20)

(20) 120 cm lang und 30 cm breit

where both clauses refer to a particular, fixed dimension, each determined by one of the two pairs of parallel edges. In order to distinguish the object conception at issue here both from the genuinely 2-D conception exemplified by boards and from the full 3-D conceptions considered up to now, we will refer to it and to the objects thus conceived as '1-2'. In our representation formalism we will use the predicate '1+2-D' to refer to objects conceived in this way. (This choice closely reflects Lang's schematic notation for these cases.)

We have phrased our explication of the predicate '1+2-D' in this way because certain objects can be conceived as '1+2-D', but do not have to. This is true in particular of block-like objects with two equal sides, such as a piece of wooden beam with a square cross section. Consider for instance piece has the dimensions 20 cm x 7 cm x 7 cm. On the one hand it can be described as having three dimensions - e.g., using PDDS, as in (21.i) (21.a)

(21) a. 20 cm hoch, 7 cm breit und 7 cm tief.

b. 20 cm lang und 7 cm dick.

But we can also describe it as in (21.b). In this last description the second clause refers to the cross section as a whole. We believe that in such cases, where the cross section is square, the thickness is measured as the length of an edge of the cross section.[5]

[5] How firm speakers are on this point we do not know. There may well be some uncertainty as to how one should proceed with objects whose cross section is some other regular polygon as well (e.g. those where the cross section is a regular triangle, as with the wrapper of a Toblerone bar.) the only fully uncontroversial case is that where the cross section is a disc, then thickness is given as the size of the disc's diameter. The predicament that the non-circular cross sections present is related to the following sense in which two-clause descriptions of '1+2-D' objects can be seen as descriptions of something two-dimensional. We might see such a description as applying to the silhouet which the object presents to the observer. In this context the clause pertaining to the size of the cross section becomes an assessment of the linear projection of the cross-section onto the transversal plane (determined by VERT and TRANS of the given PPS). If we assume, consistently with our general approach, that the main axis of the object lies within the transversal plane and the object is a cylinder (i.e. its cross secton is a disc), then the size of this projection won't change irrespective of how the object is presented . (In particular it will be invariant when the objct is rotated around its main axis.) But when the cross section is a polygon this is not so. for instance, with a square cross section the size of the projection varies between a and $\sqrt{2}$ .a, where a is the length of the sides of the cross section. We suspect that when people talk about the thickness of a generalised cylinder, there is an implication that the size which they give for it is the length of the projection just described, and thus that they presuppose that this projection is invariant under rotations of the indicated sort. When the cross section is not of cricular shape, then this presupposition is violated and the best

To repete, for ‘generalised cylinders’ with a square cross section there are the two descriptive options just mentioned, one reflecting its conception as 3-D object and the other ts conception as 1+2-D. But in all other cases (i.e. where the cross section has a different shape) only the second, ‘two-dimensional‘ option appears to be available. This is true not only for a round tower, but also (with the reservations expressed in the last foot note) for a Toblerone wrapper, an octogonal baptismal font, etc etc.

What are the options for describing objects that are conceived as 1+2-D? So far we have only spoken of those which have no functionally determined dimensions, but even for those our remarks about what combinations of adjectives are possible have so far only been incidental. first objects for which the main axis is longer than the ‘diameter of the cross section. Such objects are characterised as in (22)

$$(22)\qquad \begin{array}{llllc} & < a\ , & (b\ , & c) > & \\ < & & & & ,\ +/\text{-hollow}> \\ & < \emptyset\ , & \emptyset\ , & \emptyset > & \end{array}$$

Before we describe the possible description strategies for opbjects of this type, first a principle which holds egenrally for 1+2-D objects. The dinmension of a cross section indicated in Lang-notation as (b,c) can be described as dick if the object has the featrure +hollow; if the object has the feature +hollow, then it is sometimes possible to use weit, but often this use is not happy. (N.B. just as with 3-D objects, there are hollow 1+2-D objects which, under certain appropriate conditions, can be conceptualised as -hollow, so that the use of dick becomes possible to describe the dimension of their diameter too.)

One possible description strategy for such objects is the intrinsic strategy IDDS. According to this strategy a is described with the help of *lang* and the ‘diameter’ with the help of *dick*, and this irrespective of the object’s position. Apart from this position-independent strategy , there are also modes of description whch take the position of the object within PPS into account. Note in this connection that for 1+2-D objects there are within our simplified geometry only three distinct positions — those in which the axis a is parallel to VERT, TRANS and OBS, respectively. Of these three the third does not seem to play a significant role in position-dependent descriptions. (It appears that the fundamentally 2-dimensioal conception of 1+2-dimensional objects only those positions are conceptually relevant in which both dimensions — i.e. the axis a and the (linear projection of the) cross section are directly

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possible assessment of the thickness must involve some kind of compromise. (For a square cross section the possible values would vary between a and $\sqrt{2}$ .a, with the end points of this interval as the most plausible candidates.)

accessible to the observer O. This is true for the first two positions but not for the third.) The position dependent descriptions possible for obects satisfying (22) are easily listed. One describes the vertical dimension (i.e. the one parallel to VERT) as hoch and the other one by the adjective corresponding to its geometrical determination. Thus when a $\parallel$ VERT we get (23.a). and when a $\parallel$ TRANS we get (23.**??**)

(23) a. a $\Rightarrow$ hoch; diameter $\Rightarrow$ dick (when hollow(x) = -)

b. weit (?; when hollow(x) = +))

c. a $\Rightarrow$ lang; diameter $\Rightarrow$ hoch (???)

d. a $\Rightarrow$lang; diameter $\Rightarrow$breit (??)

e. a $\Rightarrow$ breit; diameter $\Rightarrow$ hoch (??)

In addition it seems to us just about possible to describe an object which satisfies (22) and which is in upright position (i.e. a $\parallel$ VERT) as in (23.iii). Even more marginal seems the decription of such an object in lying position (a $\parallel$ TRANS) as in (23.e), though, if we are right, even this option cannot be fully excluded.

Of the three position-dependent strategies we distinguished in connection with 3-D objects (PDDS, HODDS and VODDS), it seems that only the last two are conceivably applicable to 1+2-D objects at all. For after all we are dealing with the description of what is in essence a 2-dimensional structure and PDDS is specifically for 3-dimensions. (Cf fn. 5.) It is not obvious, however, how the possibilities listed in (23) can be viewed as the results of applying these stategies. (23.d,e) might be seen as resulting from applying HODDS to the object in upright and lying position, respectively, but we noted that these descriptions are marginal. Of the remaining two, only (23.c) could be a candidate for the application of VODDS, but it is not clear how the combination of adjectives in (23.c) could result from this application. Nor is it clear how (23.a) could be the result of applying HODDS.

It seems, rather, that position-dependent dimension descriptions of 1+2-D objects only concern the dimensions $\parallel$ VERT. These can be described with the help of hoch, whereas for the remaining, horizontal dimension one is to use the adjective which it selects according to its geometrical determination. At this moment we do not see any more insightful solution to these facts than to postulate a new position-sensitive strategy for 1+2-D objects which does just this. We leave it to the reader to introduce the formal apparatus that ought to com with the introduction of such an additional strategy hmself, or else to find a better solution to the problem, whch obviates the introduction of a new strategy.

For objects of the type given in (24) the situation is different than it is for those satisfying (22).

(24)
$$\begin{array}{lllll} <(a & ,\ b) & ,\ c> & & \\ < & & & & ,\ +/\text{-hollow}> \\ <\emptyset & ,\ \emptyset & ,\ \emptyset & > & \end{array}$$

The reason has to do with objects with the fearure -hollow. Whereas that for objects with the feature -hollow *dick* can be used to describe the diameter of a cross section schematically represented as (b,c), there is no adjective is available for the diameter of a cross section of an object with his feature when the cross section is represented as (a,b). This means that objects of this type - such as, for instance, a slice from a tree trunk, have no satisfactory intrinsic dimension description. Curiously enough such objects do allow for position-dependent descriptions when they present themselves to the observer in non-canonical positions. For instance a slice from a tree with a thickness of 10 cm and a diameter of *20 cm* which is standing on its edge can, we think, be described as in (25.a)

(25) a. 20 cm hoch und 10 cm dick. < (a,b) ⇒ hoch; c ⇒ dick)

b. 20 cm hoch und 10 cm breit. <(a,b) ⇒ hoch; c ⇒breit>

c. 10 cm hoch und 20 cm breit. <(a,b) ⇒breit; c ⇒hoch>

for the case where the object is lying in front of the observer.

In addition one may also get for this case the description given in (25.b), though again it is one that we consider marginal. And, also in analogy with what we observed for objects satisfying (22), there is the marginal description for the case where the object is lying in front of the observer.

Hollow objects satisfying (24) (e.g. a ring-like piece cut from a pipe) do not seem to allow for intrinsic descriptions. But we believe they do permit position-dependent description when it is lying down, given in (**??**.a)

(26) .

a. (a,b) → weit; c → hoch.

b. (a,b) → weit; c →breit.

Moreover, when the object is standing up, one of the two of us is prepared, when subject to enough pressure to come up with some description, to accept the one in (26.ii). But we doubt that more can be learned from this observation than the age-old truth that people are prepared to say almost anything when put on the rack.

When the diameter is big enough, (25c) might be an equally good (or equally bad) possibility as ((25b)). But it seems that we are reaching the point where returns converge on 0.

With regard to 1+2-D objects in which the two dimensions are equal - an example would be a cylinder whose height is the same as its diameter - our judgements are as uncertain as those for the case just discussed, and we see no point in dwelling on these cases separately.

2.1 What remains to be done

The later parts of our remarks on dimensional adjectives have increasingly taken on the character of a long and tedious description of data. Occasionally we could see glimpses of how the DDSs which we first introduced in conncetion with the description of block-shaped 3-dimensional objects might be applied to objects of the various types that these later parts have dealt with. But exactly how systematic or unsystematic the principles really are which govern the choice of dimensional adjectives for the description of all dimensions of all types of objects which we have reviewed is anything but transparent. To get a clearer picture of the situation it would be necessary to try to remould the definitions of the DDSs we have given in such a way that they can account for as much of data like those we have discussed in as systematic and illuminating way as possible.

Presumably such an attempt should also take into account uses of the dimensional adjectives which we have not considered here at all. For instance, Lang devotes some attention to the use of dimensional adjectives to the description of motions (such as flights, which can be described as *hoch*, or *tief*). But it doesn't emerge clearly enough from that discussion what the conceptual relations are between such uses of dimensional adjectives and the uses on which we have focused here. In addition to these there are yet other uses of these adjectives. And these two may hide some of the principles on which dimension descriptions

3 Motion

An object y may change its location over time. Such changes come about through movement e of the object in space. (We assume that there is no tele-porting!). In the description of a motion, the moving object y will be often referred to as the theme of the described motion e.

A movement of y is an event which consists in y traversing a path. This path has y's initial location - the one from which it moves - as its starting point and x's final location - the one to which it moves - as its end point. Note that the distinction between starting point and end point assigns the path an orientation. I particular when motion is a rectilinear, from one point p1 on a straight line l to another point p2 on l, then the path can be characterised as the point pair (p1,p2). This is almost like a line segment. But it is a little more in that the path (p1,p2) is not identical with the path (p2,p1). (The second path will be called the reverse of the first path.)

We assume that the path of a movement is conceived as a continuous 1-dimensional region, and that the object y which moves along it is conceived as a point (i.e. as a 0-dimensional region). (This is a conception which leaves many aspects of motion out of the picture, e.g. whether the moving object y is able to squeeze through a narrow passage, etc.)

Moreover, we will start by looking at an even more reduced conception of motion, according to which the only possible motions are rectilinear motions along one of the axes of PPS. (The notion of rectilinear motion in general, and, more generally than that, of non-rectilinear motion will considered later.) Rectilinearity of a motion entails that its path is always a line segment included in one of the axes.

At first sight the conception of motion as not only rectilinear, but in addition being always parallel to one of the axes of PPS may seem very restricted. In the practice of ordinary experience, it might be thought, few motions fit this restriction. However, the conception is not really as restricted as it seems, for we assume that the PPS in question is determined by the motion at issue. Thus, when an object y moves away from an observer O in a horizontal direction, the direction of the motion itself determines the Observer axis OBS of the relevant PPS. (So that the path of the motion is a segment of OBS. Likewise when y moves horizontally towards O. Furthermore, when y moves past O in a horizontal direction, the OBS-axis of the relevant PPS is assumed to be the line of the orthogonal projection of O's position onto the line along which y moves, so that in the PPS thus defined y moves parallel to TRANS.

Of course, not all motions are horizontal. First, there are those which are vertical (either up or down); and then there are many which are neither horizontal nor vertical but somewhere in between (as when someone walks or climbs up a steep mountain). We believe, however, that such 'oblique' motions belong to a different ('higher') level of conceptualisation and that there is a self-contained conceptual level at which all motions are seen as either horizontal or vertical.

Moreover, we think, this last conceptual level is one which clearly manifests itself in the way in which motion concepts are lexicalised. On the one hand there are verbs (relatively few, it seems, in natural languages such as German or English), that are designed explicitly for the description of vertical motions (e.g. *steigen, fallen, sinken, stürzen, heben, senken*). It might be thought that at least some of these verbs are used to describe not only perfectly (or near perfectly) vertical motions but also motions that have a non-zero vertical component. For instance *steigen* can be used to describe the progress made during a climbing tour, as when it is said of the climbers that 'Innerhalb von 2 Stunden waren sie mehr als 700 meter gestiegen'. Note however that in such descriptions the distance is measured in strictly vertical terms. In the course of the mentioned two hours the climbers are likely to have covered several kilometers of terrain. But the distance that they are specified to have moved in the sense of steigen is only the difference in the height (above sea level, say) at which they were at the start of the described motion and the height they had reached at the end. This fact is indicative that even in such cases steigen is understood as describing a purely vertical motion, the one which we get when projecting the actual path of motion onto VERT.

All strictly vertical motions are ipso facto rectilinear. This is not so for horzontal motions, since the Horizontal is a plane. Indeed, there appears to be less justification for the conceptual restriction to rectilinear motion in connection with motions in the horizontal plane. In fact, among the large number of verbs used to describe horizontal motion which we find in languages such as German or English there are hardly any which distinguish between rectilinear and non-rectilinear motion. We nevertheless believe that the fundamental conceptions of motions towards, away from and past the Observer have a special conceptual status. But we would like to have better evidence for this hypothesis than we do at the moment.

We have said that each rectilinear movement of an object y defines relative to an observer O a PPS such that the motion is parallel to one of the axes of this PPS. A special case of this is that where y and O coincide. In this case there can of course be no question of motion parallel to TRANS. (You cannot move past yourself!) We assume that from the perspective of the theme itself the PPS determined by the motion is (at any moment of time t during the motion) given by VERT and an OBS-axis which points in the direction of the motion. In the case of rectilinear motion this means that the origin of

PPS changes in the course of the motion, while its axes remain constant.

After an object y has moved rectilinearly from point p1 to point p2 during a period t1, it can perform another rectilinear motion from p2 to some further point p3 during a subsequent period t2, and it is possible in particular that this second period abuts the first: t1)(t2. The second motion can be in the same direction as the first, be in the opposite direction, be orthogonal to it, or be at any other angle (different from either 0^o, 90^o or $180)^o$. Note that this last possibility is not excluded by our current restricted conception so long as allow that the second motion 'resets' PPS. In this way we arrive at the general idea of the sum of a succession of horizontal rectilinear motions at arbitrary angles to each other.

A sum of a finite number of rectilinear motions is not the same as curvilinear motion - motion which is non-linear but nevertheless smooth. . The traditional mathematical treatment of the notion of a non-rectilinear line or line segment (i.e. of a curve) makes it possible to see any curve as the limit of a sequence of ever more refined successions of rectilinear motions, in such a way that the vertices of the finite approximations all disappear in the limit. From the perspective of the theme of motion itself, curvilinear motion is motion during which orientation of the theme changes continuously. From the perspective of an Observer O who is different from the theme the motion can still classified as either away from O, towards O, or past O,. In the first case O locates himself on a curve which includes the path of motion at a point p0 such that the starting point p1 is between p0 and p2 on the curve; in the second case he locates himself on such a curve at a point p0 such that p2 is between p0 and p1; and in the third case O sees himself as occupying a point which does not lie on such a curve, but from which there is a shortest projection onto some segment of the motion's path.

It is an interesting question whether the ordinary conception of a curve, and the notion of non-rectilinear motion as motion whose path is a segment of a curve are, in any cognitively significant sense, derived from an underlying concept of straight line and rectilinear motion, or whether they are cognitive primitives. This is a question about which (alas) we have nothing to say at present.

Among the properties of motions there are those which may be called 'purely spatial'. These are properties which can be seen as properties of the motion's path. Among them we find: (i) properties connected with the length of the path ('Er ist zehn Kilometer. gefahren.'; 'Der Ballon stieg (um) 300 Meter.'; 'Die Münze rollte acht Meter, bis sie endlich umfiel'); (ii) properties concerning the location of the path or some part thereof ('Er ist durch den Wald/auf der Landstrasse gefahren.'; Er ist (von A) nach B gefahren.'; 'Er ist in den Graben gefahren/gefallen.'; 'Er hat mich bis an die Tür gefahren/gebracht.') It is to be noted that predicating such properties takes the form of adding various phrases to the motion verb. Usually these are prepositional phrases; in just a few cases they are (accusative) NPs. (e.g. measure phrases which give the length of the path.)

Just as our developments of concepts of time and space, the motion-related notions informally described above should also be made explicit formally, i.e. via axioms. For now we only state a few of these axioms, connected with the concept of rectilinear motion, to give a flavour of what will be needed. We use Move as a 2-place predicate which relates an event e to an individual (or group of individuals) y, saying that e is a motion of y. (Often we will follow the familiar practice in discussions of motion verbs of rephrasing 'Move(e,y)' as the conjunction of the clauses 'Move(e)', and 'Theme(e) = y'.) Moreover, we use Rl as a 1-place predicate of events e saying that e is rectilinear. Our axioms assert that each motion e has a duration and a path - more precisely, we assume that there are 2-place predicates DUR and PATH, such that 'DUR(e,t)' says that t is the duration of e and 'PATH(e,lr)' say that lr is the path of e. In general lr is claimed to be a curve segment,formally: to satisfy the predicate CS. Axioms fixing the properties of curves and curve segments will still have to be supplied. (Often we will write 'dur(e) = t' and path(e) = ls instead of DUR(e,t) and PATH(e,ls), respectively.) For rectilinear motion the path is always a line segment (p1.p2), i.e. a part of some straight line l. Moreover, if t = (t1,t2), then y occupies pi at ti (for i = 1,2). And if p' is any point of lr between p1 and p2, then there is a time t' between t1 and t2 such that y occupies p' at t'.

At any moment of time t' in the course of a motion e (whether or not e is rectilinear), the motion has a definite orientation. According to the assumptions made above this is the OBS axis of the PPS determined by the motion at t' given that the theme y is taken as the observer O. This PPS determines a partition of space into two halves, the one which lies to the side of the plane through VERT and TRANS in the direction in which OBS points and the half on the other side of this plane. We will sometimes refer to the first subspace as the front of e at t' and to the other subspace as the rear of e at t'.

3.1 Axioms for motions and their paths

$$\boxed{\begin{array}{c} e\ y \\ move(e,y) \end{array}} \rightarrow \boxed{\begin{array}{c} t_1\ t_2 \\ dur(e,\ (t_1\ t_2)\ ) \\ \boxed{\begin{array}{c} t'_1\ t'_2 \\ dur(e,\ (t'_1\ t'_2)\ ) \end{array}} \rightarrow \boxed{\begin{array}{c} t'_1 = t_1 \\ t'_2 = t'_2 \end{array}} \end{array}}$$

$$\boxed{\begin{array}{c} e\ y \\ move(e,y) \end{array}} \rightarrow \boxed{\begin{array}{c} lr \\ w(e,lr) \\ curve\text{-}segment(lr) \\ \boxed{\begin{array}{c} lr' \\ w(e,lr') \end{array}} \rightarrow \boxed{lr'=lr} \end{array}}$$

Read ‘w’ ; weg (path). Read ‘lr’ : linear region 1D(w) .

$$\boxed{\begin{array}{c} e\ y\ lr \\ move(e,y) \\ Rl(e) \\ w(e,lr) \end{array}} \rightarrow \boxed{\begin{array}{c} l\ p_1\ p_2 \\ Line(p_1,\ p_2) \\ Poi(p_1)\ Poi(p_2) \\ Inc(p_1,l)\ Inc(p_2,l) \\ lr = (p_1\ p_2) \end{array}}$$

$$\boxed{\begin{array}{c} e\ y\ p_1\ p_2\ l\ p'\ p'' \\ move(e,y)\ \ Rl(e) \\ w(e,(\ p_1\ p_2)) \\ Inc(p_1,l)\ (p_2,l)\ Inc(p',l)\ \ Inc(p'',l) \\ Between(p_1,\ p'\ p'') \\ Between(p',\ p'',p_2\ ) \end{array}} \rightarrow \boxed{\begin{array}{c} t_1\ t'\ t''\ t_2\ s'\ s''\ s_1\ s_2 \\ t_1 \prec t' \prec t'' \prec t_2 \\ t_1 \subseteq s_1\quad t' \subseteq s'\quad t'' \subseteq s''\quad t_2 \subseteq s_2 \\ s_1\text{: } Occ(y,p_1)\quad s'\text{: } Occ(y,p_1) \\ s''\text{: } Occ(y,p'')\quad s_2\text{: } Occ(y,p_2) \end{array}}$$

3.1.1 axioms for betweenness relations for points on a straight line

$$\boxed{\begin{array}{c} l\ p_1\ p_2\ p_3 \\ Line(l) \\ Inc(p_1,l)\ (p_2,l)\ Inc(p_3,l) \\ p_1 \neq p_2\quad p_2 \neq p_3 \\ p_1 \neq p_3 \end{array}} \rightarrow \boxed{\begin{array}{c} Between(p_1,p_2,\ p_3) \vee \\ Between(p_2,p_1,\ p_3) \vee \\ Between(p_2,p_3,\ p_1) \end{array}}$$

$$\boxed{\begin{array}{c} p_1\ p_2\ p_3 \\ \text{Between}(p_1,p_2,\ p_3) \end{array}} \rightarrow \boxed{\begin{array}{l} p_1 \neq p_2 \\ p_1 \neq p_3 \\ p_2 \neq p_3 \end{array}}$$

$$\boxed{\begin{array}{c} p_1\ p_2\ p_3 \\ \text{Between}(p_1,p_2,\ p_3) \end{array}} \rightarrow \boxed{\begin{array}{l} \\ \text{Between}(p_3,p_2,\ p_1) \end{array}}$$

$$\boxed{\begin{array}{c} p_1\ p_2\ p_3 \\ \text{Between}(p_1,p_2,\ p_3) \end{array}} \rightarrow \boxed{\neg \boxed{\begin{array}{l} \\ \text{Between}(p_2,p_1,\ p_3\ ) \end{array}}}$$

4 The projective prepositions *über, unter, vor, hinter, links von, rechts von.*

Projective prepositions serve the purpose of describing the location of one object x - henceforth the "referent"[6]

in relation to another object, the "relatum". In such descriptions the relatum object is the referent of the NP with which the preposition is combined into a Prepositional Phrase and the referent is the referential argument of the phrase to which the PP is adjoined. In other words, what we are interested in in this section are descriptions of the form 'x (ist) *unter/.../rechts von* z'

The term *projective preposition* could be misleading. The prepositions listed in the heading of this section are all projective prepositions in that they can be used in the manner indicated. But they have other uses as well. One could hardly have expected otherwise. Prepositions are notoriously multi-purpose, and the few listed here are no exception. Projective preposition is thus strictly speaking a misnomer. One ought to speak of projective uses of these prepositions rather than of projective prepositions tout court. But we have decided not to be this fussy, and to adopt the usual terminology. Note well, however, that this has its obvious implications for the lexical entries which we will propose later on for 'projective' prepositions. These entries will only cover one use (or a small set of closely related uses) of the preposition in question. In a complete lexical entry for the preposition, which covers all its uses, the 'lexical entry' we will present here will only one anong a number of different components.

A substantial part of the meaning of the projective prepositions can be captured within the simplified conception of space, according to which there are in any given situation just three possible directions (and six orientations), given by the axes of PPS. In the context of the projective prepositions this means that the position of the referent in relation to the relatum object can have only one of the six mentioned orientations. How the referent's position in relation to the relatum object is described, i.e. which projective preposition is used, can depend on a number of different factors - the orientation of the line segment (z,x) which goes from the relatum z to the referent x, within PPS, the functionally determined intrinsic axes of z and the current position of z

[6]Perspective taking ...involves the following operations:
1. Focussing on the scene whose spatial disposition (place, path, orienation) is to be expressed. ...I call this portion the "referent".
2. Focussiong on some portion of the field w.r.t. which the referent's spatial dispositon is to be expressed. I will call this portion the "relatum".
3. Spatially relation the referent to the relatum (or expressing the referent's path or orientation) in terms of what I will call the "reference system". [Levelt:1996].

within PPS. Which preposition is actually selected depends in part on the descriptive strategy chosen. In this respect too the semantic problem that is presented by the projective prepositions is reminiscent of what we saw in our exploration of dimensional adjectives. But when we look at the details we also find considerable differences. In fact, these are so substantial that it seems artificial to retain the names of the description strategies we introduced in connection with the dimensional adjectives. It seems more honest to introduce new description strategies specifically designed for the use of the projective prepositions, and to reflect on similarities between these and the trategies for choosing dimensional adjectives afterwards. The terminology we will adopt is in lage part borrowed from the work of Levelt (See [Levelt:1996])

In the last paragraph we spoke of the line segment (z,x) connecting the relatum object z with the referent x. Evidently this makes clear sense only on the assumption that both x and z are points. Indeed, this is what we will assume for most of what we will have to say in this section. It should not be forgotten, however, that conceiving of x and z as points is an idealisation. And it is one that is especially problematic in the case of z. It is easy to see, and has often been observed, that describing the location of one object x by reference to its spatial relation to another object z is something to which we are particularly inclined to resort when z is larger (and is a more permanent landmark; the two often go together) than x. In such cases the spatial extension of z is often an important aspect of the conceptualisation of the spatial relation in which x stands to it, and ignoring it in the way we do when treating z as a point is at risk of being seriously distorting. So it is necessary to investigate the consequences of refraining from this abstraction, and we will do so towards the end of this section. Still, much can be achieved within the simplified context in which z as well as x is conceived as a point, and it is therefore within this framework that most of what we will have to say will be cast.

Recall our notation (p1,p2) for line segments. (p1,p2) denotes the line segment whose end points are p1 and p2. Thus far we have used this notation in a way which makes it symmetrical in the two arguments - (p1,p2) = (p2,p1). In the present context, however, we will also have to distinguish line segments with respect to their orientation. One way we could define such objects is as ordered pairs $\langle$ p1,p2 $\rangle$ of points, in which the order is to serve as indication of the orientation of the segment: from p1 to p2. Often we will go on the old notation (p1,p2), but with the new meaning (according to which (p1,p2) $\neq$ (p2,p1)). No harm should come from this. In particular (z,x) is the line segment whose orientation is from the relatum object z to the referent x.

Just as the dimensional adjectives do on closer inspection present a less uniform picture than one might hope for after a first perusal, this equally true of the six projective prepositions. The first division to be made within them is between *über* and *unter* on the one hand and the remaining four on the other. With very few and marginal exceptions the remaining four prepositions can be used only to describe horizontal relations between x and z, i.e. cases in which (z,x) $\|$ HOR. In other words, when (z,x) $\|$ VERT, then only *über* and *unter* are possible choices. And the choice between them is determined quite straightforwardly:

(27) Suppose that (z,x) $\|$ VERT.
(i) if Align((z,x) ,VERT), then (z,x) $\Rightarrow$ *über*;
(ii) if $\neg$ Align((z,x) ,VERT), then (z,x) $\Rightarrow$ *unter.*

As far as we can tell, this exhausts the projective uses of *unter*. But we will encounter *über* again.

4.0.2

For technical reasons, connected with the lexical entries for projective prepositions which we will give later on, it will be convenient to cast the specifications in (27) in the form of preposition assigments that are made to combinations consisting of a referent x, a relatum object z and an (otiose) observer O by a certain *Spatial Relation Description Strategy*, ASRDS (where A stands for 'Absolute'). ASRDS only assigns the prepositions *über* and *unter* to the segments (z,x) which satisfy the conditions in (i) and (ii) and is undefined for all other possibilities of (z,x).

(28) (i) if Align((z,x) ,VERT), then ASRDS(x,z,O)) $=$ *über*;
(ii) if (z,x) $\|$ VERT and $\neg$ Align((z,x) ,VERT), then ASRDS(x,z,O)) $=$ *unter*
(iii) ASRDS(x,z,O)) undefined otherwise.

The choice of prepositions to describe the horizontal relations between x and z (i.e. those cases where (z,x) $\|$ HOR) involves the choice between different strategies - the Intrinsic Spatial Relation Description Strategy ISRDS and the Deictic Spatial Relation Description Strategy DSRDS. ISRDS chooses a preposition on the basis of the relation between (z,x) and the functionally determined intrinsic axes of z. DSRDS selects prepositions on the basis of the orientation of (z,x) within the PPS determined by the relation between z and the observer O.

4.1

ISRDS is applicable only when z has at least one functionally determined axis. Just as in connection with the dimensional adjectives it is necessary to look at a substantial number of different cases one by one. In fact, the situation is worse here because we have to consider, for each type of reference object z, bot the position which z itself occupies within PPS and the relation in which x stands to it.

We will do this here only for the case where z has a complete functionally determined coordinate system, with axes which we will again designate as vert_{fun}, front_{fun} and trans_{fun}. We leave it to the reader to work out other cases for himself.[7]

We begin by considering artefacts with complete functionally determined coordinate systems. The reader is invited to think, following [Levelt:1996], about the example of a kitchen chair.

4.2

First the case where z is in its canonical position, with $\text{vert}_{fun}(z)$ aligned with VERT. In this case everything is hunky-dory: ISRDS prescribes *über* in case (z,x) is aligned with vert_{fun};[8], *unter* when (z,x) is parallel to vert_{fun}, but not aligned with it; *vor* in the case where (z,x) is aligned with $\text{front}_{fun}(z)$, ; *hinter* when (z,x) is parallel to $\text{front}_{fun}(z)$ but not aligned with it; *rechts von* in the case where (z,x) is parallel to $\text{trans}_{fun}(y)$ and pointing in the direction of forward motion of a cork screw turned from the orientation of $\text{front}_{fun}(z)$ to that of $\text{vert}_{fun}(z)$; and *links von* in the case where (z,x) is parallel to $\text{trans}_{fun}(z)$ and pointing in the opposite direction from the one just described. We repete this in (29)

(29) Suppose that z has the three functionally determined axes vert_{fun}, front_{fun} and trans $_{fun}$ and suppose that z's position is canonical in

[7]Note the degree of idealisation that is involved especially for these case in the way we have decided to proceed. On the one hand z can be conceived as having an intrinsic coordinate system only in virtue of its shape and function as a three-dimensional object. Yet in connection with its spatial relation to x we insist of conceiving it as a point. This is not necessarily inconsistent - it is quite possible for z to be on the one hand recognized as the kind of object it is, with the functional determination of axes which that entails, while on the other hand its actual size may be practically negligeable in relation ot its role as localiser of x.

[8]Note that this is consistent with the stipulation in (27) that *über* be used when (z,x) is aligned with VERT

the sense that $\mathrm{vert}_{fun} \parallel \mathrm{VERT}$. Then ISRDS assigns projective prepositions according to the following stipulations:

(i) if Align(z,x),vert_{fun}), then ISRDS(z,x,O) [9] $\Rightarrow$ *über*;
(ii) if (z,x)$\|$$\mathrm{vert}_{fun}$), but $\neg$Align(z,x),vert_{fun},
then ISRDS(z,x,O) $\Rightarrow$ *unter*;
(iii) if Align(z,x),front_{fun}), then ISRDS(z,x,O) $\Rightarrow$ vor;
(iv) if (z,x)$\|$$\mathrm{front}_{fun}$), but $\neg$Align(z,x),front_{fun}), then ISRDS(z,x,O) $\Rightarrow$ hinter;

(v) if (z,x)$\|$$\mathrm{trans}_{fun}$), and Align((z,x),v), where v is the vector determined by the cork screw principle applied to the vector pair (front_{fun},vert_{fun}), then ISRDS(z,x,O) $\Rightarrow$ *rechts von*;
(vi) if (z,x)$\|$$\mathrm{trans}_{fun}$), and $\neg$Align((z,x),v), where v is the vector determined by the cork screw principle applied to the vector pair (front_{fun},ver_{fun}), then ISRDS(z,x,O) $\Rightarrow$ *links von*.

As soon as z is not in its canonical position, however, things become more tangled. ISRDS still 'wants' to asign the same prepositions, but now there are competing considerations and often these win out.

The most important impediment is this. Recall that if z is not in canonical position, then vert_{fun} is not aligned with VERT. This means that if (z,x) is aligned with VERT, then the intrinsic specification given in (29) will conflict with the requirement of (27) that (z,x) be described with the help of *über*. And as far as we can see, this requirement almost always wins out (But see the discussion of animal reference objects below.)

There are four non-canonical positions for z that we have to consider, one in which it is upside down, one in which it is lying on its side, one in which it lying on its front and one in which it is lying on its back. We take these in turn, as best we can.

4.2.1

(a) When z is lying on its side, then front_{fun} is parallel to HOR. This might suggest that the intrinsic characterisation of a segment (z,x) that is aligned with front_{fun} with the help of *vor* and a segment that is parallel to front_{fun} but not aligned with it, with *hinter*. And indeed, it appears that these descriptions are possible when z is positioned in th way we are considering.

[9] We follow the same practice which we adopted earlier in connection with IDDS: Even though the ISRDS is, just like IDDS, independent of O, we include o as an argument for reasons of uniformity

(b) trans_{fun} is now parallel to VERT and no intrinsic use of *rechts* and links is possible, in accordance with (27), which overrides these options with its absolute assignments of *über* for the cse where (z,x) is verital and pointing upwards, and *unter* for the case where (z,x) is vertical and pointing downwards

(c) We also have in the case under consideration that $\text{vert}_{fun} \|$ HOR. So the question arises whether the intrinsic assignment of *über* and *unter* to line segments (z,x) parallel to vert $_{fun}$ are still possible. As far as we can tell (from our own intuitions as well as the findings reported in [Levelt:1996]), this possibility marginally exists for *über* but doesn't seem to exist at all for *unter*: That is:

(30) (i) if $\text{Align}((z,x),\text{vert}_{fun})$, then $\text{ISRDS}(z,x,O) \Rightarrow(?)$ *über*;
(ii) if $(z,x) \| \text{vert}_{fun}$ but $\neg$ $\text{Align}((z,x),\text{vert}_{fun})$, then ISRDS(z,x,O) undefined.

4.2.2

. Now consider the case where z is lying on its front.

(a) Now $\text{front}_{fun} \|$ VERT. This means that the overriding power of (27) blocks the use of *vor* and *hinter*.

(b) $\text{trans}_{fun} \|$ HOR, which suggests the possibility of using *rechts* and *links*, and indeed it appears that these designations are possible when (z,x) $\| \text{trans}_{fun}$.

(c) Also $\text{vert}_{fun} \|$ HOR. as in the subsection above. There appers to be a marginal possibility for using *über* for an x such that (z,x) is aligned with vert_{fun} but no possibiity for using *unter* when (z,x) points in the opposite direction.

4.2.3

The case where z is lying on its back does not seem to differ from that where it is lying on its front.

4.2.4

z is lying/standing upside down. We personally find this case particularly confusing.

(a) Fairly clear is the following. In this case $\text{vert}_{fun} \|$ VERT. However, vert_{fun} and VERT point in opposite directions so that the absolute assigment of (27) and the intrinsic assignment of (29) are still in conflict.

(b) Both front_{fun} and trans_{fun} are parallel to HOR. This might suggest that intrinsic assignments to segments that are parallel to either of these axes might be possible. Are they? we don't know. In fact, we have found ourselves particularly at a loss in connection with this case. Perhaps the fact that it is much more of an effort to mentally rotate z back into its canonical position from one that is 180^0 away from it than it is from a positon only 90^0 away (cf. Shepherd (??)) has got something to do with this.

Before we leave ISRDS, a very brief remark on reference objects that are living beings, in particular humans. We have been assuming up to now that the specifications given by (27) cannot be overruled. It seems that as long as z isn't an animal, this is correct. But when z is an animal, it is possible for cases where (z,x) $\|$ VERT can be nevertheless described with the help of a preposition other than *über* or *unter*, and one which is chosen intrinsically. One example is a person who is in a sleeping position and lying on his side, so that his cheeks are horizontal and one, - let's say the left one - resting on the pillow. Suppose that x is a fly whirring at a distance of only a few centimeters vertically above the person's nose. Then it seems possible to describe x as being *rechts von* the person's nose, even though (z,x) is aligned with VERT.

We presume that the reason why in this case (27) can be overruled is that the position of the fly is still to the right of the person's nose from the person's own perspective. The circumstance that the person happens not to be upright (i.e. in his or her 'canonical position') carries little weight when considered in the context of what matters in such a situation: the possibilities of getting rid of the fly. The actions which are typically performed to bring this about (such as trying to swat the fly) are guided by kinaesthetic perception and from that perspective to the right of the nose is to the right of the nose whether one is standing up, sitting lying on one's back or lying on one's side. People, one might say, take their intrinsic coordinate system with them when they go ot bed.

4.3

We now come to the deictic strategy for choosing projective prepositions. As we said, according to this strategy prepositions are selected on the basis of the orientation of (z,x) vis-a-vis PPS.

The coordinate axes of PPS are VERT, OBS and TRANS, and again we have to consider the six possible orientations that (z,x) can have with respect to them.

(a) Two of these cases are straightforward, since they have been decided already by the stipulations in (27): If (z,x) is aligned with VERT, we get *über*, if it is parallel to VERT but not aligned with it, we get *unter*.

(b) The choice of *vor* and *hinter* are determined on the basis of the principle that the 'deictic front' of z is the part which faces O. That is, the relation between z and O determines for z a vector front_d which is parallel to OBS but points in the opposite direction. If (z,x) is aligned with front_d, then DSRDS assigns it the preposition *vor*, if it points in the opposite direction (i.e. in the same direction as OBS), then the preposition is *hinter*.

(c) *rechts von* and *links von* are determined from the perspective of O: x counts as *rechts von z* if O, when facing z, has to turn right in order to face x; and analogously for *links von*.

Note that the different perspectives which determine *vor/hinter* and *rechts/links* according to the deictic perspective have the effect that they are no longer related by cork screw principles in the same way as that is the case for ISRDS. Applying the principles of (29.v,vi) we would predict *rechts* and *links* to be used in just the opposite way from the one they are. We do not want to exclude the possibility at this point that there might be different way of accounting for these particular facts than the one we have given. But if we are right, then the deictic strategy for choosing *rechts* and *links* is fundamentally different from the deictic principle for assigning *vor* and *hinter*. The former are determined directly form the perspective of the observer himself. the latter are determined from the perspective of z, but on the basis of deictically determined front.

The assignments given by DSRDS can be summarised as follows:

(31) (i) if Align(z,x),VERT), then DSRDS(z,x,O) $\Rightarrow$ *über*;
(ii) if (z,x)$\|$VERT), but $\neg$ Align(z,x),VERT), then DSRDS(z,x,O) $\Rightarrow$ *unter*;
(iii) if Align(z,x),front_d), then DSRDS(z,x,O) $\Rightarrow$ vor;
(iv) if (z,x)$\|\text{front}_d$), but $\neg$Align(z,x),front_d), then DSRDS(z,x,O) $\Rightarrow$ *hinter*;
(v) if (z,x)$\|\text{trans}_d$), and Align((z,x),v), where v is the vector determined by the cork screw principle applied to the vector pair (front_d,vert_d), then ISRDS(z,x,O) $\Rightarrow$ links von;
(vi) if (z,x)$\|\text{trans}_{fun}$), and $\neg$ Align((z,x),v), where v is the vector determined by the cork screw principle applied to the vector pair (front_d,vert_d), then DSRDS(z,x,O) $\Rightarrow$ *rechts von*;

We are now in a position to present lexical entries for the projective prepositions along the same lines as we did for dimensional adjectives: Having described how the prepositions get selected by the different strategies for the purpose of describing spatial relations defined by line segments (z,x) we get entries for the prepositions by 'inverson' of those strategies.

We use in essence the same scheme for representing the lexical information that we adopted earlier for the dimensional adjectives. Of course there are some obvious differences. The projective prepositions which concern us here have besides the referential argument x (the "referent", according [Levelt:1996]) also a second argument, which is the referent of the dative NP governed by the preposition. (Note well: we are only concerned here with the 'stative', or 'locative', use of projective prepositions, which requires the NP to be in the dative. The directional use, which is signalled by accusative case marking of the NP governed by the preposition, will be considered later.

4.4 Lexical entries for projective prepositions

(32)

	preposition	NP, Dative
	x	z
Selectional Restrictions	material Object(x)	Material Object(z)

Application Conditions:
The set of pairs <?SRDS,O> of a SRDS ?SRDS and an observer position O vis-avis z such that ?SRDS assigns preposition to the arguments combination (x, z, O).
Formally:
{ <?SRDS,O>: ?SRDS(x,z,O) = preposition }
Semantic Representation:
The propositional function which maps each of the pairs <?SRDS,O> onto true or false, depending whether ?SRDS(x,z,O) = preposition Formally:
λ <?DSRDS, O>. ?SRDS(x,z,O) = preposition

4.5 Sizable relatum objects

So far we have ignored the spatial extension of the referent x and the relatum object z. As said at the outset of our discussion of the projective prepositions, we do not consider it essential for our present concerns to draw back from this abstraction as far as x is concerned. But the matter is different with regard to z. Often we describe the location of a referent in terms of its relation to a relatum object z which is much bigger than it; and especially in such cases the size of z often does matter to the conceptualisation which motivates the use of the chosen preposition. For instance, consider the intrinsic strategy for using projective prepositions in relation to a 'large' relatum object with a complete functionally determined coordinate system such a building with a well-defined front. It is unquestionable that we can describe a car as *vor dem Gebäude* (in front of the building) so long as the car is within the rectangular horizontal region which is bounded on one side by the facade of the building (more precisely: by the intersection of the building's facade with the horizontal plane HOR, spanned by the axes OBS and TRANS of PPS); on the two adjacent sides by the two vectors aligned with frontf whose origins are the end points of the facade (at the level of the horizontal plane) and whose fourth side is at some distance from the building in front of it. (More about this fourth side in the next section.). But as soon as the car is on the other side of either one of the 'sidelines' of this rectangle, describing its location as *vor dem Gebäude* becomes problematic. We take this to be a fairly clear fact: If x is an object that is 'on the ground' (i.e. whose location is conceived as part of the horizontal plane HOR that is spanned by OBS and TRANS), then its location can be unequivocally correctly described as 'vor z' (with *vor* used in the sense of ISRDS) when x is within the rectangular part of HOR just described. More generally, x can be unequivocally described in these terms when its location is within the generalised cylinder whose cross section is the facade, whose axis is parallel to frontf which is bounded on one end by the facade and which is on the side indicated by frontf. (This generlisation applies not only to objects on the ground but also birds or balloons which hover at some ditance above it.)

The same goes for the other projective prepositions. Generalising from what was said in the last paragraph:

> A relatum object z with functionally determined coordinate system, and whose size is taken to matter for the intrinsic use of the projective presuppositions outward-projects in each of the six orientations parallel to front_f, vert_f and trans_f a cylinder c such that
>
> (i) the main axis of c is parallel to the given orientation
>
> (ii) the cross section of c is the projection of the object onto the plane perpendicular to this orientation and has the shape of that part of the object's surface which is on the side of the orientation.
>
> We can now modify the lexical entries for the projective prepositions as follows:

> x is correctly described as '*prep z*' - where *prep* is one of the six projective prepositions - as long as x is located within the cylinder determined by z and the intrinsic orientation to which prep corresponds.

This condition turns the entries for these prepositions which we gave earlier into the descriptions of 'limit cases', where the size of z is 'allowed to go to zero'. The effect of going to this limit is that the cylinders of which we have just spoken all contract into line segments.

So much for the intrinsic use of projective prepositions in relation to non-punctiual reference objects. We also have to reconsider the absolute use and the deictic use. For the absolute use, which only concerns über and *unter*, we need the same qualifications which we have just discussed in connection with the intrinsic use. We believe that this is also true of the deictic use. But here, we think, the matter requires a little discussion.

First, we have to reassess the preconditions for the deictic use of projective prepositions in relation to a non-punctual reference object. We will restrict our attention here to objects z whose surface consists of two horizontal and four vertical faces. Given this assumption about z we believe that the canonical relation between z and O which is presupposed by the deictic use of the projective prepositions is this: The vertical part of z that is visible from the position of O consists of a single face, and (consequently) the perpendicular from O to this face will intesect the face itself (rather than intersect the straight line which the face shares with HOR at some point outside the face).

Given that this conditon obtains, we could now imagine the following alternative rule for the use of '(x ist) vor z'. The unequivocal cases falling under this description are those where the line going through O and x intersects the face of z that presents itself to O. This rule requires that x be located within the triangle whose vertices are O and the two end points of the line segment which the face shares with HOR. Intuitively the rule says that O can descrsibe x as 'vor z' if and only if O can see x as aligned with some part of z.

This alternative rule defines as the region consisting of all the possible possitions for the deictic use of 'vor z' a triangle whose base is the face of z facing z. Or, more accurately, the intended region is that part of the triangle which includes the base and which is cut off from it by the fourht boundary spoken of above, whose discussion is still to come. This cut-off triangle is properly included in the rectangular region defined by the rule we formulated above in our discussion of the intrinsic use.

Which of these two poroposals is right? In other words, what are we to say about those cases which qualify as instances of 'vor z' according to the earlier rulebut not according to the one under discussion? We suspect that speakers' intuitions are not entirely clear or consistent on this point. But our own intuitions suggest to us quite strongly that the earlier, more liberal rule is correct for the deictic use of vor as well as for its intrinsic use. We have this intuition also in relation to the other five projective prepositions. In fact, in connection with *über, unter, rechts von* and *links von* our intuitions are even stronger than they are in connection with *vor*.

On the strength of these intuitions we propose the old rule, involving the cylinders projected outwards by z in the relevant directions, as the one which governs the deictic use of the projective prepositions just as it does the intrinsic and the absolute use.

How close must x be to z? There is one question connected with the use of the projective prepositions which we have been staunchly ignoring up to now. This is the question: How close must x be to z in order that it can be described as 'prep z', where prep is one of our six presuppositions? To give just one example, when O is at a distance of 100 m. from a house z, and a car x parked 5 m from the house in a location that is in between it and O, then describing x as 'vor z' seems to be unproblematically correct. When on the other hand x, while still between O and z, is 5 m away from O (and thus 95 m. from z), then describing x as 'vor z' would seem marginal at best; and in oour own judgement the decsription would simply be wrong.

Even if this is true, however, it doesn't tell us exactly how close x must be to z in order to satisfy the description 'vor z'. But of course there is no answer to this question. What we are facing here is a particularly striking instance of the ubiquitous *sorites paradox (or Paradox of the Heap)* [10] This

[10]This paradox was discovered in antiquity and is associated with the Megarians, a philosophical School which distinguished itself especially through its identification and discussion of problems in philosophical logic and the theory of meaning. (Unfortunately only a very small part of the writings of members of this school has survived, but still eough to let us guess at the importance of its contributions.) The instances of the pardox that have survived to this day and are still standardly used to explain what the problem is are (i) the paradox of the heap or ßoritesänd (ii) the bald man paradox. The first: take one grain of salt and put it by itself on the table before you. This clearly isn't a heap. Add another grain, you still don't seem to have a heap. keep doing this. At one point you will have a heap. But when? If it any time you haven't got a heap yet, then adding one grain to what you shouldn't get you a heqap either. For how could one grain make the difference between something qualifying as a heap and its not doing so? But clearly this principle - that one grain cannot make the difference - is inconsistent with the fact that (a) one grain doesn't make a heap; and () a sufficient (but finite) number of grains together does. The paradox of the bald man tells the same story but starting from the opposite end: A

paradox demonstrates in a particularly poignant way the inherent vagueness which can be detected in virutally any predicate that is used in describing the physical world (in essence: every predicate that doesn't belong to pure mathematics or logic). Vague predicates are predicates for which there are (or could be) entities (fitting the sortal restrictions of the predicate) for which it is indeterminate whether they belong to the predicate's extension or not. Predicates which exemplify the sorites paradox illustrate the additional, and more disturbing fact that the ways in which we understand and describe the world in which we live is based on principles which, when pushed to the limit, are plainly inconsistent.

If this is so, how is it possible that we perceive and act upon the world in ways which are at least potentially coherent and rational? The only hope that we can harbour of demonstrating this to be so in a form that might carry conviction istht we may succeed in making it plausible that human thought and behaviour are governed not only by the principles which which govern sorites-like predicates and which lead to contriduction when pushed to the hilt, but in addition by a further principle, which keeps us from pushing application of the other principles to the point where inconsistency becomes inescapable. Alas, a really satisfactory argument to this effect is, we believe, still outstanding.

There does exist, however, an argument, which though it doesn't achieve what the missing argument would achieve, but which draws attention to something that is just as important for our present concerns. Assume that normal situations allow us to draw back or stay away from the brink of inconsistency that is built into the semantics of any sorites-like predicate. This entails that in the situations in which we actually make use of such predicates there always is a non-empty truth value gap for them: A set of real or possible entities of the right sort for which it is indeterminate whether or not they belong to the predicate's extension. And where there is such a truth value gap it is possible for us to uphold the notion (even if it is ultimately illusory) that there is a sharp dividing line running through the truth value gap which separates the objects which 'really are in the predicate's extension after all' from those which 'really are outside the extension'. Such a dividing line can't be anything more than a figment of our imagination, fostered by a desire for a clear and simple logic. But whether fictitions or not, it enables man to reason with vague predicates as if they were sharp and thus to apply to them the laws of classical predicate logic.

man with 200.000 hairs on his head is definitely not bald Pull one of his hairs out. That surely won't make him bald. Go on this way, Eventually you wil have reduced the man to baldness. But at which point exactly does he become bald?

The argument which yields this result - that the use of classical logic in application to vague predicates is legitimate - is known as the *supervaluation analysis of vagueness.* [11] Basically the supervaluation argument is this: No matter where the dividing lines for the different vague predicates are drawn, the compositional semantics for sentences containing these predicates will assign truth values (with respect to any model which incorporates a particular choice of dividing lines) in such a way that the laws of classical logic are validated. So the employer of vague predicates is entitled to make use of these laws as long as he accepts that dividing lines could be drawn somewhere through the truth value gaps, even if he is fundamentaly incapable of saying with any accuracy where such dividing lines should be drawn.

Important for our present purposes is the conception that such lines can be drawn somehow, and that in much of what we do with the vague predicates that natural language makes available to us we assume that the dividing lines do in some sense exist. It is important in particular in connection with our use of the projective prepositions. Takevor. Part of the conception underlying the use of expressions of the form 'vor z' is that the cylinders pointng outward from z which we introduced in the last section not only have an end at the surface of z itself, but that there also is an opposite end to them. This other end (also a cross section of the cylinder, and necessarily of the same shape as the one which bounds z) is determined by a plane which plays the role of the dividing line of which we have just spoken, viz. that of the dividing line which cuts through the truth value gap of the predicate lx. vor(x,z).

We will assume, then, that for each relatum object z (and for any time t) a 'dividing plane' is taken as 'given', which provides the missing bound for the cylindirical region that demarcates the loctions of those objects x which satisfy λ x. vor(x,z) (at t) from those which do not. By analogy we assume that there are similar dividing 'planes' for each of the other five projective prepositions.

4.5.1 Directional uses of projective prepositional phrases

German has the possibility of using the projective prepositions not only to describe the (current) location of an object - we will refer to these uses

[11] The idea was to our knowledge first formulated by Michael Dummett in the late sixties in his paper "Wang's Paradox", which appeared in print only in the 1975 volume of the journal Synthese. The first more detailed elaborations of the idea can be found in Fine's "Vagueness, Truth and Logic" which appeared in the same issue of Synthese and Kamp's Two Theories of Adjectives"which appeared in the same year in Keenan(ed.) Formal Semantics for Natural Languages. These last two papers were presented in 1973 (almost at the same time, though on different occasions) and their findings were arrived at fully. independently.

henceforth as theirlocative uses - but also to describe motions of the object as ending in such a location. These latter uses will be called directional. The directional uses of projective prepositions are related to their locative uses in the same way that directional uses of spatial prepositions are related to their locative uses generally. (In Section ?? below we will address the evident fact that there are many more location-describing prepositions than the six projective ones with which we have been concerned so far.) On the face of it, this relation between directional and locative uses is a morphological one: In locative uses the NP governed by the preposition is in the Dative, in directional uses it is in the Accusative.

Semantically, directional phrases are the inchoative counterparts of the correspondinf locatives. To be more explicit, locative phrases describe states - locational states of the object x that is being described. Often these states are non-permanent: Many objects, and among them many of those whose locations we quite naturally describe in the relational terms that involve projective prepositions, are movable - they move themselves, or cn be moved by others, from one location to the next. Thus the location states in which such an object is at any time are non-permanent; they cease to obtain as soon as the object moves or is moved.

The way in which we do justice to the non-permanence of location states is by the usual device of representing locational predications as the obtaining of some state s, where s' temporal location can then be specifeid separately. Thus we can (schematically) represent the statement that x is vor z as:

(33) s: vor'(x,z,O) [12]

Information about the time t when the predicaton state obtains can be specified by an additional clause of the form 't $\subseteq$ s'.

The claim that directional phrases are the inchoatives of the corresponding locatives can now be explicated as follows. Directional phrases describe changes into a state of the type described by the locative phrase from a previous state which is not of this type. As usual, the claim that the object x in question is at first in a state not satisfying the locative description functions as a presupposition. So we can represent the inchoative meaning of a directional phrase of the schematic form 'prep_{acc}(x,z)' (where 'prep_{acc}' is to indicate that the preposition governs an NP in the accusative) as in

[12] Here 'vor'(x,z,O)"stands proxy for the information which the semantic part of thel exical entry for vor will tell us about what such a predication actually means.

PRESUPPOSITION NON-PRESUPPOSITIONAL

(34) $$\boxed{\begin{array}{c} s^{pr} \\ {}^{pr}\text{: } \neg\ \text{prep}_{acc}(\text{x,z}) \end{array}} \quad \boxed{\begin{array}{c} \text{e} \\ \text{s}_0 \bigcirc \text{e} \\ \text{e: BEC } (\lambda\ \text{s}_1.\ \boxed{\text{s}_1\text{:prep}_{acc}(\text{x,z})}\ ) \end{array}}$$

Note that (34) does not explicitly describe e as a motion of x. However, it is a simple fact of life that changes in location can only be brought about through motion. Consequently, directional phrases are compatible only with adjunction sites which describe motions. More formally, when a directional phrase is used grammatically as an adjunct (and in our experience it almost always is), then it must be adjoined to a phrase whose referential argument is a motion event.

It is especially in connection with the interpretation of directional phrases that the vague boundaries of the locative regions which determine the truth conditions of predications involving the projective prepositions become crucial. For instance, it seems perfectly possible to describe the event of a car which drives up to a house in a direction perpendicular to its front (e.g. along a lane which leads straight up to the house from a distant gate) and which stops in front of the main entrance to the house with the words:

(35) Das Auto fuhr vor das Haus.

The intuition here is that the car was at first too far from the house to admit the locative description vor dem Haus, but then traverses at some point the boundary between the part of the horizontal plane where the description is not appropriate and the part where it is, and thereby enters the realm where the description is correct. Evidently, this boundary is precisely the dividing line of which we spoke in connecion with the vagueness of projective prepositions.

To summarise, the conception of changing from a state which does not fit the description to one which does fit it makes sense only if we can think of the motion as involving the crossing of some kind of boundary which separates the relevant spatial regions.

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