SFB/TR 8 SPATIAL COGNITION

Technical Report

GUM-Space

The Generalized Upper Model spatial extension: a linguistically-motivated ontology for the semantics of spatial language

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I1-[OntoSpace]
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This document describes the spatial extension of the *Generalized Upper Model 3.0* (GUM). GUM is a general task and domain independent, linguistically motivated ontology. It provides a general representation of the semantics of German and English. In particular, it supports natural language processing while simplifying the interface between domain-specific knowledge and general linguistic resources.

The parts of the model that are described in this report concern space, spatial language and further concepts that are involved specifically in spatial linguistic expressions. This report provides a complete description of the spatial extension of GUM together with examples of spatial expressions and their specification.

The spatial component of GUM 3.0 has been developed in the project I1-[OntoSpace] of the SFB/TR8 Spatial Cognition collaborative research center. This documentation also provides a manual for defining spatial language in terms of GUM specifications.

Contents

1 Introduction to the Generalized Upper Model

The Generalized Upper Model 3.0 (GUM 3.0) is a linguistically motivated ontology, which aims primarily to mediate between natural language and application components. It is based on the semantic perspective of natural language as described in Halliday and Matthiessen [1999] (the *ideational* level). Hence, GUM's concepts are influenced strongly by the lexicogrammar of natural language to be applied in any kind of domains. The complete model and all of its concepts and principles are described in detail in Bateman et al. [1995, 2007].

1.1 GUM's spatial extension

The spatial extension of GUM refines the model with aspects of space. This allows GUM to be used particularly for space-intensive language applications involving mobile robots operating in complex spatial environments. Our current focus on the spatial subarea within our ontology is motivated by the prominent status of spatial thought within cognition, e.g., Lakoff and Johnson [1999], Gärdenfors [2000], Gattis [2001], and likewise spatial language within linguistics, including the investigation of both literal [Coventry and Garrod, 2004, Carlson and van der Zee, 2005] and derived [Boroditsky, 2000, Tyler and Evans, 2003] spatial meanings.

A general overview of GUM's spatial categories, its underlying experimental linguistic results and language analysis are described in Bateman et al. [2010].[1]. This document explains the spatial concepts in detail with examples from natural language and their ontological specifications.

[1] The current specification of the Generalized Upper Model 3.0 is defined in OWL DL and CASL. The versions can be found on `http://www.ontospace.uni-bremen.de/ontology/gum.html`, together with specification samples.

1.2 General Structure of GUM

The general structure of GUM 3.0 can be split into the concept and the relation hierarchy. The first contains all concepts having the top entity GUMThing while the latter contains all relations between concepts having the top entity gumrelation.

GUMThing has three subtypes, Element, Configuration and MultiConfiguration, which correspond to the concepts *elements*, *figure* and *sequence* described in Halliday and Matthiessen [1999]. Element subsumes single objects or conceptual items, which participate as constituent parts in configurations. Linguistically, they are expressed by verbal groups, nominal groups, adverbial groups, prepositional phrases, and conjunction groups. Configuration subsumes activities or states of affairs, i.e., representations of experience, which are expressed at the level of the clause. A MultiConfiguration, finally, describes a sequence of configurations, as expressed by a clause complex that reflects dependencies between single clauses. Thus, the three subtypes represent three different levels of complexity of entities that are related in various ways to each other, as defined by the relation hierarchy. For example, an Element may act as a participantInConfiguration in a Configuration.

Configurations that are relevant for spatial specifications are SpatialLocating (subconcept of BeingANDHaving), which represents static spatial configurations, and the concepts NonAffectingSpatialDoing and AffectingSpatialDoing (subconcepts of NonAffectingAction and AffectingAction respectively), which represents dynamic spatial configurations.

Elements that are particularly involved in the spatial configurations are GeneralizedLocation (subconcept of Circumstance) describing the location of an entity and SpatialModality describing the spatial modality between two or more entities. In the broader sense Process states the type of an activity, in this case a spatial activity, while subconcepts of SimpleThing can be involved as participants in this activity.

The complete relational hierarchy is shown in Figure 1.2. Its top concept gumrelation represents the most abstract relation of the Generalized Upper Model, which corresponds to *roles* in Halliday and Matthiessen [1999].[2]

Relations that are involved in spatial configurations are locatum, relatum, all subrelations of attribute, spatialPerspective, extremePosition, accessibility, reciprocalRelation, hasEnhancement, hasExtension and hasSpatialModality. locatum and relatum typically take part in a relating configuration, such as SpatialLocating. Additional information about spatial configurations can be expressed by using attributes. spatialPerspective, extremePosition, accessibility, reciprocalRelation, hasEnhancement and hasExtension defines modifications or refinements that occur in spatial expressions. hasSpatialModality relates a

[2] In the notion of OWL DL these relations refer to properties.

concrete SpatialModality to a configuration. Other subrelations of participantInConfiguration, however, can occur in spatial configurations as well, for instance, actor or actee in a motion process.

In the following, we give a detailed description of GUM's spatial components starting with concepts from configuration and element. Each concept that is involved in spatial configurations and that is also part of the spatial extension of GUM will be introduced and exemplified. Relations are described together with the concept examples and specified in detail in Section 4.

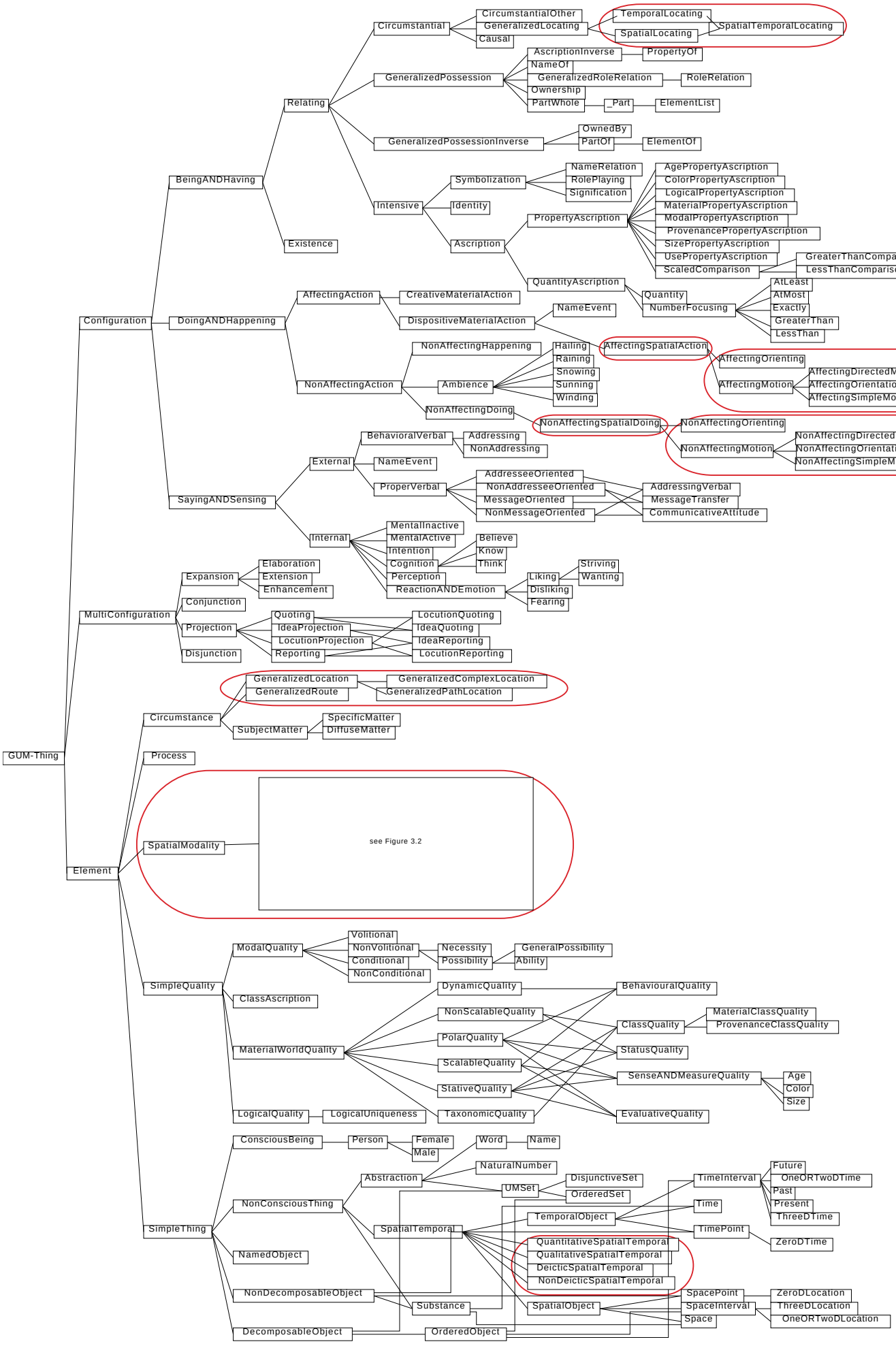

Figure 1.1: Conceptual Hierarchy

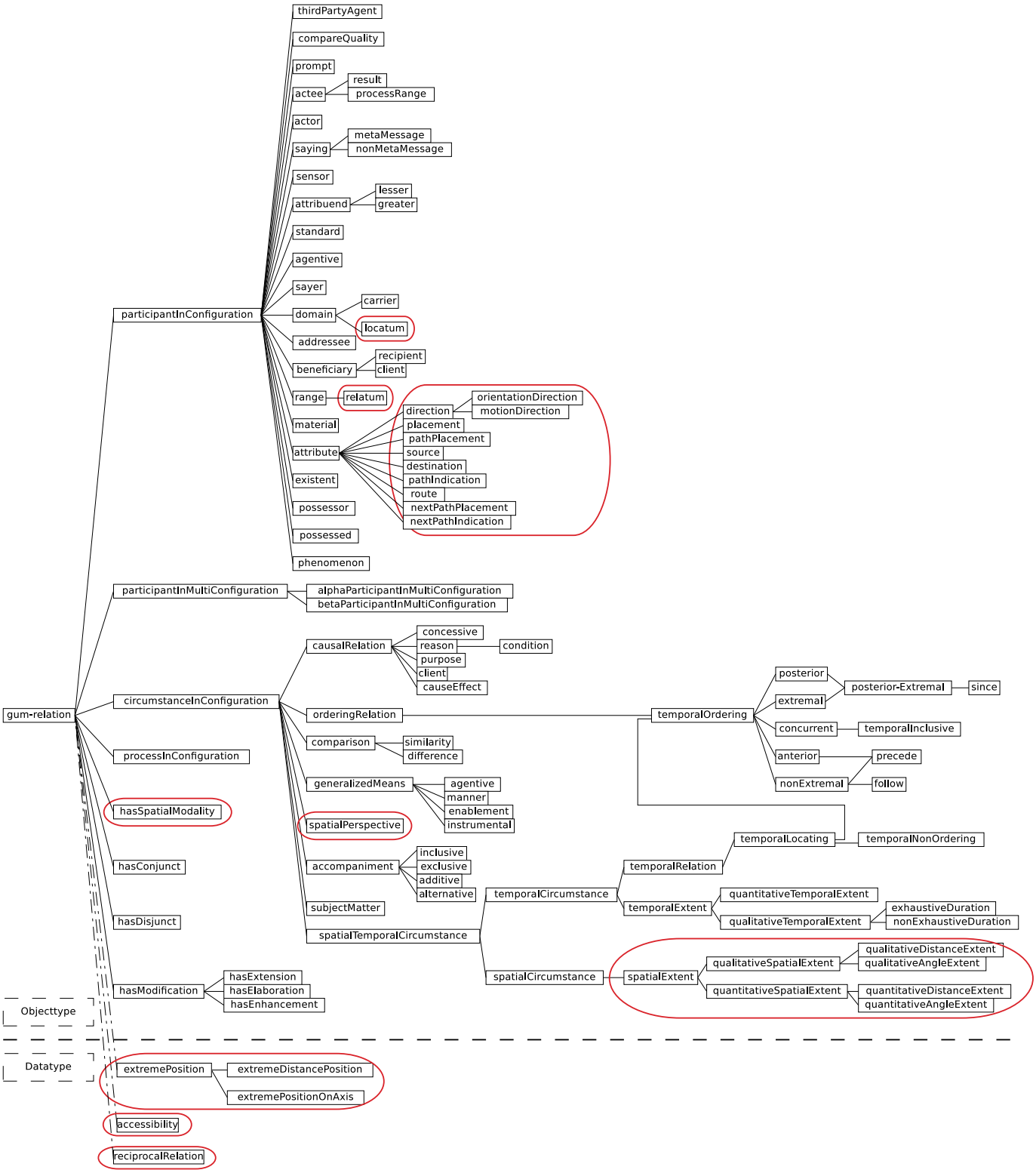

Figure 1.2: Relation Hierarchy

2 Spatial configurations

A Configuration is the basic fragment of experience that embodies one quantum of change [Halliday and Matthiessen, 1999]. It is the totality of all the elements participating in some activity or state of affairs [Bateman et al., 1995]. Configurations are expressed at the level of the clause. They consist of exactly one process, participants taking part in this process, and associated circumstances, and they unfold in time. Configurations concerning space are specified by SpatialLocating, NonAffectingSpatialDoing and AffectingSpatialDoing.

2.1 SpatialLocating

The concept SpatialLocating is subsumed under GeneralizedLocating, a category that defines general locations of entities in space, time, or abstract places. As a subconcept of Circumstantial, it defines a circumstantial relationship that relates an entity (*attribute*) to its cause (*domain*) in space, time, abstract space, or other circumstance-like entities [Bateman et al., 1995]. The taxonomic dependencies of SpatialLocating are illustrated in Fig. 2.1.

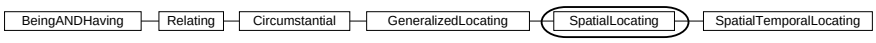

Figure 2.1: Upper Concepts of Spatial Locating

Static spatial relationships are specified by the concept SpatialLocating. This category represents any configuration whose function it is to locate some object in space. It defines a locatum, an entity (SimpleThing) that is located with respect to a specific placement. The placement of a SpatialLocating is given by a GeneralizedLocation or GeneralizedRoute. SpatialLocating also defines a Process that plays the processInConfiguration (the relationships is specified by the concept Configuration).

Examples of SpatialLocating instances are given in the following. Details of GeneralizedLocation and GeneralizedRoute are described in Section 3.1 and 3.2 respectively.

Example 2.1: A hat is on the rack.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'hat' A hat
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'rack' the rack
          hasSpatialModality Support 'sup1' on
```

Example 2.2: It is at the top.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'it' It
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'top'
          hasSpatialModality Proximal 'prox1' at
AND
SpatialLocating 'sl2'
     locatum SimpleThing 'top'
     processInConfiguration Process -undefined-
     placement GeneralizedLocation 'gl2'
          relatum SimpleThing -undefined-
          hasSpatialModality AboveProjection 'ap1' the top
```

Example 2.3: It curves away from there.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'it' It
     processInConfiguration Process 'curving' curves
     placement GeneralizedRoute 'gr1'
          source GeneralizedLocation 'gl1'
               relatum SimpleThing -undefined-
               hasSpatialModality GeneralDirectional 'gd1' from
               accessibility false (low) there
          destination GeneralizedLocation 'gl2'
               relatum SimpleThing -undefined-
               hasSpatialModality Distal 'd1' away
```

2.1.1 SpatialTemporalLocating

As a subconcept of SpatialLocating, SpatialTemporalLocating also relates an object to its spatial circumstance. In addition, SpatialTemporalLocating is also a subconcept of

TemporalLocating and relates the object to a temporal placement (temporalLocating). In particular, this object has to be an event (NonConsciousThing).

Example 2.4: The meeting is in the Cartesium at three o'clock. (The meeting is at three o'clock and the meeting is in the Cartesium).

```
SpatialTemporalLocating 'stl1'
     locatum NonConsciousThing 'meeting' The meeting
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'cartesium' the Cartesium
          hasSpatialModality Containment 'con1' in
     temporalLocating TimePoint 'three-o-clock' at three o'clock
```

However, this example is different from a pure SpatialLocating that only defines additional temporal information, and that relates a physical object instead of an event:

Example 2.5: He was at the cinema at nine o' clock. (*He was at the cinema and he was at nine o'clock.)

```
SpatialLocating 'stl1'
     locatum SimpleThing 'he' He
     processInConfiguration Process 'being' was
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'cinema' the cinema
          hasSpatialModality Proximal 'pro1' at
     temporalLocating TimePoint 'nine-o-clock' at nine o'clock
```

2.2 NonAffectingSpatialDoing

Dynamic spatial actions of an entity (*actor*) that do not affect other entities (*actees*) are specified by a NonAffectingSpatialDoing. This category defines an actor and the processInConfiguration of the action. A placement, where the spatial action takes place, can be defined as well. The concept NonAffectingSpatialDoing is subdivided into specific types of spatial actions, orientations or motions, namely NonAffectingMotion and NonAffectingOrienting, shown in Figure 2.2.

2.2.1 NonAffectingMotion

NonAffectingMotion represents motion configurations in which the actor performs a spatial movement. It is subdivided into the concepts NonAffectingDirectedMotion, which

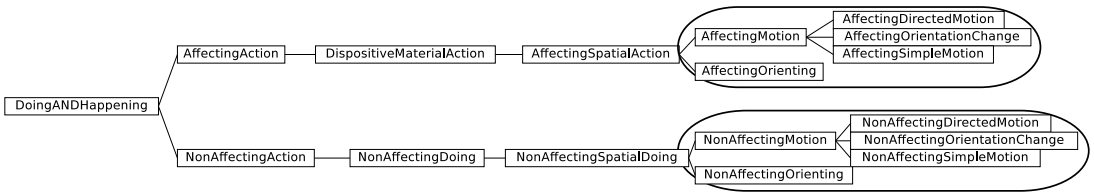

Figure 2.2: Upper Concepts of NonAffectingSpatialDoing and AffectingSpatialAction

describes spatial motions that are indicated by a direction, NonAffectingOrientationChange, which describes spatial re-orientations of entities, and NonAffectingSimpleMotion, which describes underspecified spatial actions.

2.2.1.1 NonAffectingDirectedMotion

A NonAffectingDirectedMotion defines a spatial action, in which the direction or the path of the motion is given. This information can be expressed in different ways:

- by a motionDirection depending on the actor, e.g. "He goes upward", "He walks forward".
- by a direction in case a re-orientation of the motion or direction takes place, e.g. "Turn left"
- by a route that defines the locations source, pathPlacement, pathIndication, or destination, e.g. "He went out of the house, through the garden, past the barn, to the gate"

Example 2.6: The man walked forward.

```
NonAffectingDirectedMotion 'nadm1'
     actor SimpleThing 'man' The man
     processInConfiguration Process 'walking' walked
     motionDirection GeneralizedLocation 'gl1'
          relatum SimpleThing 'man'
          hasSpatialModality FrontProjectionExternal 'fpe1' forward
```

Example 2.7: Go up over the old pine.

```
NonAffectingDirectedMotion 'nadm1'
     actor SimpleThing -undefined-
     processInConfiguration Process 'going' Go
     motionDirection GeneralizedLocation 'gl1'
          relatum SimpleThing -undefined-
```

```
        hasSpatialModality SpecificDirectional 'fpe1' up
    route GeneralizedRoute 'gr1'
        pathIndication GeneralizedPathPlacement 'gpp1'
            relatum SimpleThing 'old pine' the old pine
            hasSpatialModality OverProjectionExternal 'ope1' over
```

Example 2.8: Turn left.

```
NonAffectingMotion 'nam1'
    actor SimpleThing -undefined-
    processInConfiguration Process 'turning' Turn
    direction GeneralizedLocation 'gl1'
        relatum SimpleThing -undefined-
        hasSpatialModality LeftProjection 'lp1' left
```

Example 2.9: The train raced through the tunnel.

```
NonAffectingDirectedMotion 'nadm1'
    actor SimpleThing 'train' The train
    processInConfiguration Process 'racing' raced
    route GeneralizedRoute 'gr1'
        pathPlacement GeneralizedPathPlacement 'gpp1'
            relatum SimpleThing 'tunnel' the tunnel
            hasSpatialModality PathRepresentingInternal 'ope1' through
```

2.2.1.2 NonAffectingOrientationChange

This motion configuration specifies a change in orientation of an actor. It can be expressed by an orientationDirection or a route. In case a route is defined, the route cannot specify intermediate points on the path, i.e. pathPlacement or pathIndication.

Example 2.10: Wende dich nach links.

```
NonAffectingOrientationChange 'naoc1'
    actor SimpleThing 'Du' dich
    processInConfiguration Process 'wenden' wende
    orientationDirection GeneralizedLocation 'gl1'
        relatum SimpleThing -undefined-
        hasSpatialModality LeftProjectionExternal 'lp1' nach links
```

Example 2.11: Turn from the kitchen 90 degrees to the left to the office.

```
NonAffectingOrientationChange 'naoc1'
    actor SimpleThing -undefined-
```

```
processInConfiguration Process 'turning' turn
route GeneralizedRoute 'gr1'
     source GeneralizedLocation 'gl1'
          relatum SimpleThing 'kitchen' the kitchen
          hasSpatialModality GeneralDirectional 'gd1' from
     source destination 'gl2'
          relatum SimpleThing 'office' the office
          hasSpatialModality GeneralDirectional 'gd1' to
orientationDirection GeneralizedLocation 'gl3'
     relatum SimpleThing -undefiend-
     hasSpatialModality LeftProjectionExternal 'lp1' to the left
          quantitativeAngleExtent QuantitativeSpatialTemporal '90-degrees'
90 degrees
```

2.2.1.3 NonAffectingSimpleMotion

A NonAffectingSimpleMotion specifies a spatial action without information about locations of the motion. A general location, i.e. a placement, where the motion takes place may be expressed though.

Example 2.12: He is dancing.

```
NonAffectingSimpleMotion 'nasm1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'dancing' is dancing
```

Example 2.13: He is dancing in the street.

```
NonAffectingSimpleMotion 'nasm1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'dancing' is dancing
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'street' the street
          hasSpatialModality Containment 'con1' in
```

2.2.2 NonAffectingOrienting

NonAffectingOrienting specifies a spatial configuration (happening) by using orientation information and therefore requires an orientationDirection that is filled by a GeneralizedLocation.

Example 2.14: The compass needle points north.

```
NonAffectingOrienting 'nao1'
     actor SimpleThing 'compassNeedle' The compass needle
     processInConfiguration Process 'pointing' points
     orientationDirection GeneralizedLocation 'gl1'
          relatum SimpleThing -undefined-
          hasSpatialModality North 'n1' north
```

2.3 AffectingSpatialAction

A AffectingSpatialAction defines a spatial action that affects an entity, the *actee*. In general, the actor modifies the location or orientation of the actee. Similar to NonAffectingSpatialDoing, AffectingSpatialAction is divided into two subconcepts, namely AffectingOrienting and AffectingMotion.

Their definitions correspond to non-affecting orienting and motion configurations. In contrast to non-affecting configurations, affecting configurations define the relation actee, i.e. the entity who is affected by the configuration. In correspondence to non-affecting configurations, AffectingMotion defines the subconcepts AffectingDirectedMotion, AffectingOrientationChange and AffectingSimpleMotion.

2.3.1 AffectingMotion

AffectingMotion represents motion configurations in which an actor spatially affects an actee. It is subdivided into the concepts AffectingDirectedMotion, AffectingOrientationChange, and AffectingSimpleMotion.

2.3.1.1 AffectingDirectedMotion

(similar to NonAffectingDirectedMotion, but affecting an actee)

Example 2.15: He puts the ball in the box.

```
AffectingDirectedMotion 'adm1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'putting' puts
     actee SimpleThing 'ball' the ball
     route GeneralizedRoute 'gr1'
          destination GeneralizedLocation 'gl1'
               relatum SimpleThing 'box' the box
               hasSpatialModality Containment 'con1' in
```

2.3.1.2 AffectingOrientationChange

(similar to NonAffectingOrientationChange, but affecting an actee)

Example 2.16: He turns it over.

```
AffectingOrientationChange 'aoc1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'turning' turns
     actee SimpleThing 'it' it
     orientationDirection GeneralizedLocation 'gl1'
          relatum SimpleThing -undefined-
          hasSpatialModality SpecificDirectional 'sd1' over
```

2.3.1.3 AffectingSimpleMotion

(similar to NonAffectingSimpleMotion, but affecting an actee)

Example 2.17: He swirled the water.

```
AffectingSimpleMotion 'asm1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'swirling' swirled
     actee SimpleThing 'water' the water
```

2.3.2 AffectingOrienting

(similar to NonAffectingOrienting, but affecting an actee)

Example 2.18: He pointed the camera at her.

```
AffectingOrienting 'ao1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'pointing' pointed
     actee SimpleThing 'camera' the camera
     orientationDirection GeneralizedLocation 'gl1'
          relatum SimpleThing 'she' her
          hasSpatialModality GeneralDirectional 'gd1' at
```

3 Elements in spatial configurations

3.1 GeneralizedLocation

A GeneralizedLocation is the spatial-functional entity that represents relative positions of entities. It is minimally defined by a spatial modality and a (potentially undefined) relatum. Its subconcepts are shown in Figure 3.1. GeneralizedLocation's upper concept Circumstance fills circumstantial roles in configurations and most of these circumstantial elements embody some feature of grammatical metaphor [Halliday and Matthiessen, 1999, p. 221]. Of those that do not, the most usual are those of time, place, manner, quality, and intensity [Halliday and Matthiessen, 1999, p. 351].

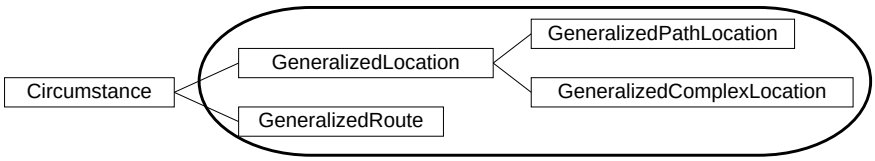

Figure 3.1: Concepts of GeneralizedLocation

Example 3.1: (The group is) in Australia.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'group' The group
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'australia' Australia
          hasSpatialModality Containment 'con1' in
```

Example 3.2: To the right.

```
direction GeneralizedLocation 'gl1' to
     relatum SimpleThing -undefined-
     hasSpatialModality RightProjection 'rp1' the right
```

Example 3.3: Above the rocket warehouse.

```
placement GeneralizedLocation 'gl1'
     relatum SimpleThing 'RocketWarehouse' the rocket warehouse
     hasSpatialModality AboveProjection 'ap1' above
```

3.1.1 GeneralizedComplexLocation

This element specifies the location in a SpatialLocating or other non-abstract configurations. It is minimally defined by a spatial relation and a *complex* relatum, which has to be a DecomposableObject or consist of more than one entity, i.e. GeneralizedComplexLocation constraints the type of the relatum.

Example 3.4: (The pedestrian stood) among the crowd.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'pedestrian' The pedestrian
     processInConfiguration Process 'standing' stood
     placement GeneralizedComplexLocation 'gcl1'
          relatum DecomposableObject 'crowd' the crowd
          hasSpatialModality Distribution 'dist1' among
```

3.1.2 GeneralizedPathLocation

GeneralizedPathLocation defines an optional successor by the relations nextPathPlacement and nextPathIndication. This location is used in pathPlacement or pathIndication relations of a route to represent lists of path placements.

Example 3.5: The dog ran across the field (and) along the river (at the same time).

```
NonAffectingDirectedMotion 'nadm1'
     actor SimpleThing 'dog' The dog
     processInConfiguration Process 'running' ran
     route GeneralizedRoute 'gr1'
          pathPlacement GeneralizedPathLocation 'gpl1'
               relatum SimpleThing 'field' the field
               hasSpatialModality PathRepresentingInternal 'rpi1' across
          pathPlacement GeneralizedPathLocation 'gpl2'
               relatum SimpleThing 'river' the river
               hasSpatialModality PathRepresentingExternal 'rpe1' along
```

Example 3.6: The dog ran across the field (and then) along the river.

```
NonAffectingDirectedMotion 'nadm1'
     actor SimpleThing 'dog' The dog
```

```
processInConfiguration Process 'running' ran
route GeneralizedRoute 'gr1'
     pathPlacement GeneralizedPathLocation 'gpl1'
          relatum SimpleThing 'field' the field
          hasSpatialModality PathRepresentingInternal 'rpi1' across
          nextPathPlacement GeneralizedPathLocation 'gpl2' (and then)
               relatum SimpleThing 'river' the river
               hasSpatialModality PathRepresentingExternal 'rpe1' along
```

3.2 GeneralizedRoute

GeneralizedRoute represents a route description of static or dynamic spatial configurations. It may define sources, pathIndications, pathPlacements, and destinations.

Example 3.7: In Bremen he ran from his room, out of the house, across the street, past the post office, over the bridge, into the park, to the fountain.

```
NonAffectingDirectedMotion 'nadm1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'running' ran
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'bremen' Bremen
          hasSpatialModality Containment 'con1' in
     route GeneralizedRoute 'gr1'
          source GeneralizedLocation 'gl2'
            relatum SimpleThing 'his-room' his room
            hasSpatialModality GeneralDirectional 'gd1' from
          pathPlacement GeneralizedPathLocation 'gpl1'
            relatum SimpleThing 'house' the house
            hasSpatialModality DenialOfFunctionalControl 'dfc1' out of
            nextPathPlacement GeneralizedPathLocation 'gpl2'
              relatum SimpleThing 'street' the street
              hasSpatialModality PathRepresentingInternal 'rpi1' across
              nextPathIndication GeneralizedPathLocation 'gpl3'
                relatum SimpleThing 'postoffice' the post office
                hasSpatialModality PathRepresentingExternal 'rpe1' past

                nextPathPlacement GeneralizedPathLoation 'gpl4'
```

```
                relatum SimpleThing 'bridge' the bridge
                hasSpatialModality PathRepresentingInternal 'pri2' over

                nextPathPlacement GeneralizedPathLocation 'gpl5'
                   relatum SimpleThing 'park' the park
                   hasSpatialModality Containment 'con1' into
        destination GeneralizedLocation 'gl3'
          relatum SimpleThing 'fountain' the fountain
          hasSpatialModality GeneralDirectional 'gd2' to
```

Example 3.8: The road runs from Hamburg to Bremen.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'road' The road
     processInConfiguration Process 'running' runs
     route GeneralizedRoute 'gr1'
          source GeneralizedLocation 'gl1'
               relatum SimpleThing 'hamburg' Hamburg
               hasSpatialModality GeneralDirectional 'gd1' from
          destination GeneralizedLocation 'gl2'
               relatum SimpleThing 'bremen' Bremen
               hasSpatialModality GeneralDirectional 'gd2' to
```

3.3 Process

A Process is the linguistic construal of "goings-on" or events [Halliday and Matthiessen, 1999]. Processes are similar to configurations, but factor out participants, circumstances, and other elements. They are a necessary property of a configuration, linguistically mostly expressed as verbs. Regarding processes that are involved in spatial configurations, they usually express motion or static positioning.

3.4 SpatialModality

Any spatial description contains information concerning the type of relationship being described. This information is typically expressed by a spatial preposition, an adverb, or an adjective. In GUM, this crucial spatial expression is given by the concept SpatialModality. It fills the relation hasSpatialModality of a GeneralizedLocation and represents the type of spatial relationship between a locatum and a relatum in a static configuration, or an actor and a relatum in a dynamic configuration. It is

strongly structured by empirical, linguistic results in natural language (cf. Section 1). The most general distinction between spatial modalities is whether they represent distance between entities (SpatialDistanceModality), or functional dependencies between entities (FunctionalSpatialModality), or positions between entities relative to each other (RelativeSpatialModality). An overview of all spatial modalities is shown in Fig. 3.2.

3.4.1 SpatialDistanceModality

The element indicates some qualitative or quantitative distance information within a spatial relation. It is solely representing a distance between two or more entities, independent of the entities' features, orientations, shapes, or any other information. It is therefore different from RelativeSpatialModalities (see Section 3.4.3).

3.4.1.1 QualitativeDistance

The entity QualitativeDistance represents any spatial relation involving an explicit qualitative distance component, possibly assessed using functional criteria. If the related objects have spatial contact or not results from the preposition.

Example 3.9: The house is by the river.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'house' The house
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'river' the river
          hasSpatialModality QualitativeDistance 'qd1' by
```

3.4.1.1.1 Distal A qualitative spatial relation indicates functionally large distance between the locatum and the relatum. This modality can be enhanced by a qualitative expression that indicates the distance.

Example 3.10: The house is far away from the river.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'house' The house
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'river' the river
          hasSpatialModality Distal 'd1' away from
          qualitativeDistanceExtent QualitativeSpatialTemporal 'far' far
```

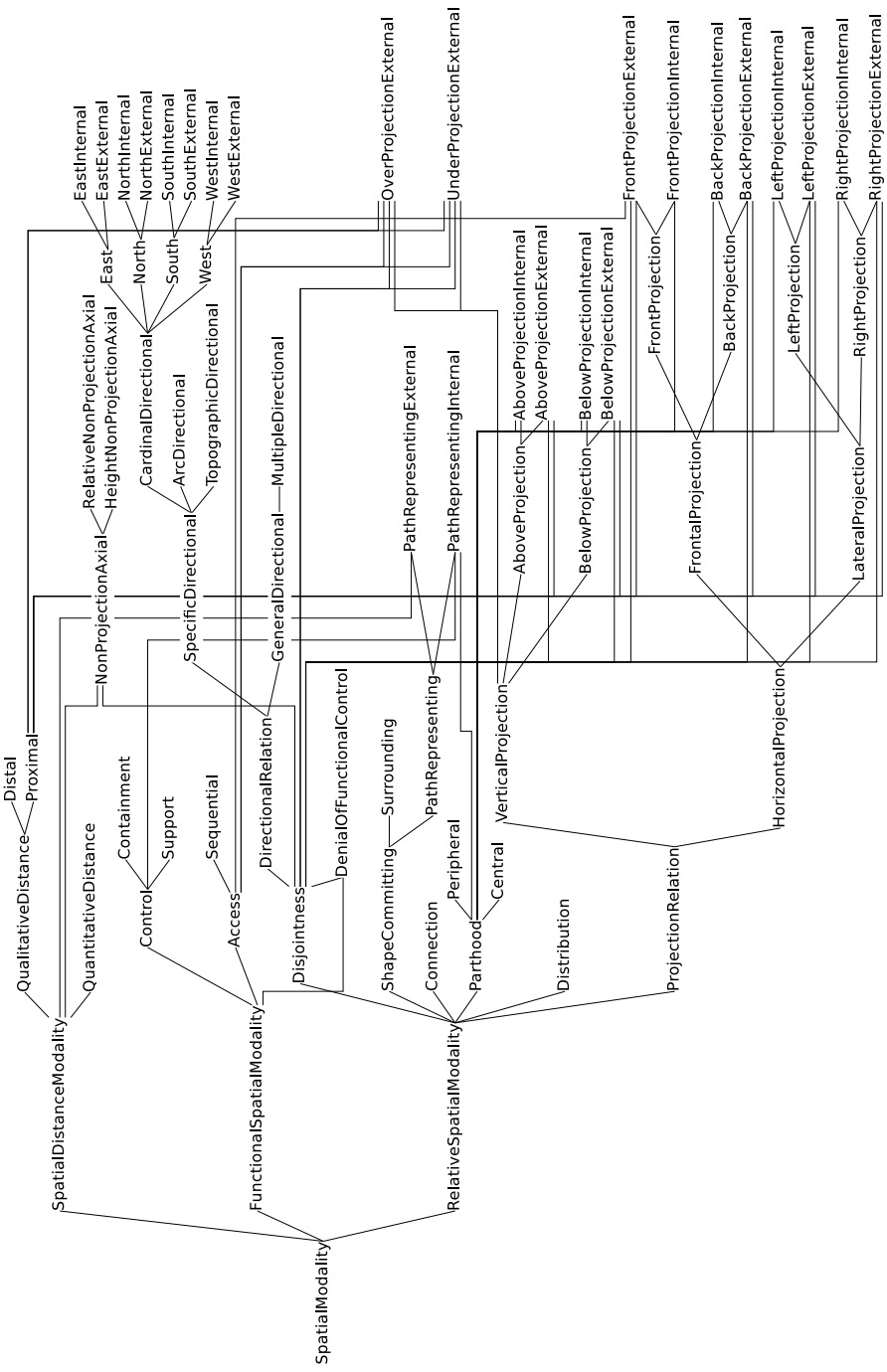

Figure 3.2: Concepts of SpatialModality

3.4.1.1.2 Proximal A qualitative spatial relation indicating relative proximity. This relation indicates Access.

Example 3.11: The house is very close to the river.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'house' The house
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'river' the river
          hasSpatialModality Proximal 'p1' close to
          hasEnhancement QualitativeSpatialTemporal 'very' very
```

3.4.1.2 QuantitativeDistance

Any spatial relation that encodes distance expressed by metric information.

Example 3.12: The house is 20 meters from the motorway.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'house' The house
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'motorway' the motorway
          hasSpatialModality QuantitativeDistance 'qd1' from
          quantitativeDistanceExtent SimpleThing '20meters' 20 meters
```

3.4.2 FunctionalSpatialModality

The most general type of functional relations [Bateman et al., 2006] that describes functional properties in the relation of entities.

3.4.2.1 Access

Access is a functional relation holding between two spatial objects x and y, such that y is physically accessible from x for some purpose as intended by an agent [Bateman et al., 2006]. It is often further specified, for instance, as a FrontProjectionExternal, a OverProjectionExternal, a Sequential, or an UnderProjectionExternal.

3.4.2.1.1 Sequential The spatial modality Sequential defines spatial relations expressed by temporal aspects.

Example 3.13: The library is after the shops.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'library' The library
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'shops' the shops
          hasSpatialModality Sequential 'sec1' after
```

In case entities are defined by sequential information, they specify a SequentialQuality.

Example 3.14: Exit the roundabout at the third exit.

```
NonAffectingDirectedMotion 'nadm1'
     actor SimpleThing -undefined-
     processInConfiguration Process 'exiting' exit
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'exit'
               + hasQuality SequentialQuality 'third' the third exit
          hasSpatialModality Proximal 'pro1' at
     route GeneralizedRoute 'gr1'
          source GeneralizedLocation 'gl2'
               relatum 'roundabout' the roundabout
               hasSpatialModality GeneralDirectional 'gd1'
```

3.4.2.2 Control

Control is a binary functional relation holding between two spatial objects x and y, such that x controls y's position in space: if x moves, then y moves as well, but x and y need not be in contact [Bateman et al., 2006]. Control is further subdivided into Containment and Support.

3.4.2.2.1 Containment Containment is a functional relation that holds between two spatial objects x and y, such that x functionally contains y. x, however, need not spatially contain y [Bateman et al., 2006].

Example 3.15: The seed is in the ground.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'seed' The seed
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
```

```
        relatum SimpleThing 'ground' the ground
        hasSpatialModality Containment 'con1' in
```

3.4.2.2.2 Support A functional relation holding between two spatial objects x and y, such that x physically supports y in the presence of gravity; x and y need not be in contact [Bateman et al., 2006].

Example 3.16: The pen is on the table.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'pen' The pen
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'table' the table
          hasSpatialModality Support 'sup1' on
```

3.4.2.3 DenialOfFunctionalControl

DenialOfFunctionalControl is the direct opposite to Control and also a subconcept of Disjointness.

Example 3.17: The ball is off the grass.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'ball' The ball
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'grass' the grass
          hasSpatialModality DenialOfFunctionalControl 'dfc1' off
```

3.4.3 RelativeSpatialModality

A relation that is represented by the element RelativeSpatialModality denotes the position of an object in space. It serves to define entities such as place by providing constraints that are relational in nature, that is, accompanied by a (potentially unspecified) relatum. RelativeSpatialModalitys are usually grammatically expressed as prepositions. Different from SpatialDistanceModality, this concept depends on features of each object in the relation, such as its instrinsic front, shape, and axial orientation.

3.4.3.1 Connection

A connection relation spatially connects the locatum to the relatum. Here, the locatum and the relatum cannot be spatially disjunct.

Example 3.18: He is touching the screen.

```
AffectingSimpleMotion 'asm1'
     actor SimpleThing 'he' He
     processInConfiguration Process 'touching' touches
     actee SimpleThing 'screen' the screen
```

3.4.3.2 Parthood

In a Parthood spatial modality, the locatum is topologically part of the relatum. All internal ProjectionRelations are subconcepts of Parthood. Also, Central and Peripheral are subconcepts of Parthood.

3.4.3.2.1 Central A Central spatial modality defines the relationship between locatum and relatum based on the central part of the relatum.

Example 3.19: The box is in the middle of the room.

```
SpatialLocating 'SL1'
     locatum SimpleThing 'box' The box
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'GL1'
          relatum SimpleThing 'room' the room
          hasSpatialModality Central 'C1' in the middle of
```

3.4.3.2.2 Peripheral A Peripheral spatial modality defines the relationships between locatum and relatum based on the peripheral part of the relatum.

Example 3.20: He stood on the edge of the cliff.

```
SpatialLocating 'SL1'
     locatum SimpleThing 'He' He
     processInConfiguration Process 'standing' stood
     placement GeneralizedLocation 'GL1'
          relatum SimpleThing 'cliff-edge'
          hasSpatialModality Support 'S1' on
SpatialLocating 'SL2'
     locatum SimpleThing 'cliff-edge'
```

```
processInConfiguration Process 'undefined'
placement GeneralizedLocation 'GL2'
      relatum SimpleThing 'cliff' cliff
      hasSpatialModality Peripheral 'P1' the edge of
```

3.4.3.3 Disjointness

A spatial relation between two objects, in which both objects do not have contact or connections. This entity is therefore disjoint from Connection. Disjointness can be further specified by NonProjectionAxial, DenialOfFunctionalControl, DirectionalRelation, and all external ProjectionRelations.

3.4.3.3.1 NonProjectionAxial A projective, axial relation that also provides the functionality SpatialDistanceModality. If a reference system is involved, the axis has to be lateral [Bateman et al., 2006], represented by its subconcept RelativeNonProjectionAxial. If gravity is involved, the axis has to be vertical, represented by the subconcept HeightNonProjectionAxial.

3.4.3.3.1.1 RelativeNonProjectionAxial The relative spatial modality that is represented by axial (lateral) spatial relations.

Example 3.21: The lamp is beside my head.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'lamp' The lamp
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'myhead' my head
          hasSpatialModality RelativeNonProjectionAxial 'rnpa1' beside
```

Example 3.22: You are in the line of the cross.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'you' You
     processInConfiguration Process 'being' are
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'cross' the cross
          hasSpatialModality RelativeNonProjectionAxial 'rnpa1' in the line of
```

3.4.3.3.1.2 HeightNonProjectionAxial The relative spatial modality in which gravity information is involved, referring to a vertical axis.

Example 3.23: The fish is deep down.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'fish' The fish
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing -undefined-
          hasSpatialModality HeightNonProjectionAxial 'hnpa1' deep down
```

3.4.3.3.2 DirectionalRelation DirectionalRelation is a spatial relation that indicates a specific direction, which could be given by a vector.

3.4.3.3.2.1 SpecificDirectional This spatial relation is expressed by a direction. It can be further separated into CardinalDirectional, expressed by a cardinality, i.e. East, North, South, West, ArcDirectional, expressed by clock directions, such as "at four o'clock", and TopographicDirectional, expressed by topographical aspects, such as "uphill", "downhill", etc.

Example 3.24: The house is to the north of the town.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'house' The house
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'town' the town
          hasSpatialModality North 'n1' to the north of
```

Example 3.25: The fridge is at three o'clock.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'fridge' The fridge
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing -undefined-,
          hasSpatialModality ArcDirectional 'arc1' at three o'clock
```

Example 3.26: It is three miles uphill from here.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'it' It
     processInConfiguration Process 'being' is
```

```
      placement GeneralizedLocation 'gl1'
            relatum SimpleThing -undefined-
            hasSpatialModality TopographicDirectional 'top1' uphill
                  quantitativeSpatialExtent QuantitativeSpatialTemporal '3miles'
three miles
            spatialPerspective SimpleThing 'here' from here
```

3.4.3.3.2.2 GeneralDirectional This general directional relation is expressed by a direction particle, such as "to", "from". Its meaning, however, is derived by the relation in which it occurs.

Example 3.27: The cat leapt to the desk.

```
NonAffectingDirectedMotion 'nadm1'
      actor SimpleThing 'cat' The cat
      processInConfiguration Process 'leaping' leapt
      route GeneralizedRoute 'gr1'
            destination GeneralizedLocation 'gl1'
                  relatum SimpleThing 'desk' the desk
                  hasSpatialModality GeneralDirectional 'gd1' to
```

Example 3.28: A woman came from the villa.

```
NonAffectingDirectedMotion 'nadm1'
      actor SimpleThing 'woman' A woman
      processInConfiguration Process 'coming' came
      route GeneralizedRoute 'gr1'
            source GeneralizedLocation 'gl1'
                  relatum SimpleThing 'villa' the villa
                  hasSpatialModality GeneralDirectional 'gd1' from
```

Example 3.29: Take an engine from Avon to Bath.

```
AffectingDirectedMotion 'adm1'
      actor -undefined-
      processInConfiguration Process 'taking' take
      actee SimpleThing 'engine' an engine
      route GeneralizedRoute 'gr1'
            source GeneralizedLocation 'gl1'
                  relatum SimpleThing 'Avon' Avon
                  hasSpatialModality GeneralDirectional 'gd1' from
            destination GeneralizedLocation 'gl2'
```

```
        relatum SimpleThing 'Bath' Bath
        hasSpatialModality GeneralDirectional 'gd2' to
```

A subconcept of GeneralDirectional is MultipleDirectional. This spatial modality represents diverse directions.

Example 3.30: They walk around town.

```
NonAffectingDirectedMotion 'nadm1'
     locatum SimpleThing 'they' They
     processInConfiguration Process 'walking' walk
     direction GeneralizedLocation 'gl1'
          relatum SimpleThing 'town' town
          hasSpatialModality MultipleDirectional 'md1' around
```

3.4.3.4 Distribution

The concept Distribution differs from all other categories because it requires a *complex* relatum, i.e. a decomposable entity or a plural expression. Therefore, it can only be used in cases of GeneralizedComplexLocations. Prepositions like *among* and *between* are indicating this concept.

Example 3.31: The house is among the trees.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'house' The house
     processInConfiguration Process 'being' is
     placement GeneralizedComplexLocation 'gcl1'
          relatum SimpleThing 'trees' the trees
          hasSpatialModality Distribution 'd1' among
```

3.4.3.5 ProjectionRelation

Projective spatial relations involve a reference system, in which the axis is determined by the term, such as "left", "right", "above". The axis can be vertical (below or above) or horizontal (front, back, lateral (left or right)) [Bateman et al., 2006]. Projective relations are either internal, where the locatum is a part of the relatum, or external, where a certain distance is indicated, which is proximal by default, and the objects are disjoint or they have an external spatial contact.

3.4.3.5.1 HorizontalProjectionRelation This relation holds for horizontally oriented relations. It can be further divided into FrontalProjection with its subconcepts FrontProjection

and BackProjection and LateralProjection with its subconcepts LeftProjection and RightProjection. All of these concept can be internal or external.

Example 3.32: The ball is to the right of the box.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'ball' The ball
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'box' the box
          hasSpatialModality RightProjectionExternal 'rpe1' to the right of
```

3.4.3.5.2 VerticalProjectionRelation This relation holds for vertically oriented relations. It can be further distinguished if the object is above, AboveProjection, or below, BelowProjection. Both of these subconcepts can be internal or external. If Access is involved, a vertical projective relation can be distinguished between OverProjectionExternal and UnderProjectionExternal.

Example 3.33: The box is under the table.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'box' The box
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'table' the table
          hasSpatialModality UnderProjectionExternal 'up1' under
```

3.4.3.6 ShapeCommitting

This relation commits to a specific shape of the relatum. In combination with the preposition "through", for instance, we can derive certain shape information, if the respective object provides the possibility that other objects can "go" through it.

3.4.3.6.1 PathRepresenting This shape committing relation is represented by an inherently given path.

3.4.3.6.1.1 PathRepresentingExternal An external, path representing relation that indicates a distance, proximity as default. It results from the respective expression, if the related objects have contact.

Example 3.34: The deer fled along the field.

```
NonAffectingDirectedMotion 'nadm1'
     locatum SimpleThing 'deer' The deer
     processInConfiguration Process 'fleeing' fled
     route GeneralizedRoute 'gr1'
          pathPlacement GeneralizedPathLocation 'gpl1'
               relatum SimpleThing 'field' the field
               hasSpatialModality PathRepresentingExternal 'pre1' along
```

3.4.3.6.1.2 PathRepresentingInternal An internal, path representing relation that at least indicates a topological overlap of both objects.

Example 3.35: The duck was swimming through the pond.

```
NonAffectingDirectedMotion 'nadm1'
     locatum SimpleThing 'duck' The duck
     processInConfiguration Process 'swimming' was swimming
     route GeneralizedRoute 'gr1'
          pathPlacement GeneralizedPathLocation 'gpl1'
               relatum SimpleThing 'pond' the pond
               hasSpatialModality PathRepresentingInternal 'pri1' through
```

3.4.3.6.2 Surrounding The concept Surrounding describes the relation between two objects, in which one of them surrounds topologically the other one. If the objects have contact or not, results from the expression. One possible preposition is "around".

Example 3.36: The river surrounds the town.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'river' The river
     processInConfiguration Process 'surrounding' surrounds
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'town' the town
          hasSpatialModality Surrounding 'sur1' surrounds
```

3.5 SimpleThing

This is the most general entity which may participate in a configuration. Some of them can occur in spatial actions or situations. As SimpleThings generally can be part of a configurations, they can consequently be part of spatial configurations too. So far,

GUM's spatial extension does not make specific distinctions of spatial entities. They are defined by spatial modalities, such as "top" or "bottom".

Particular SimpleThings of the spatial extension, however, are NonDeicticSpatialTemporal, DeicticSpatialTemporal, QualitativeSpatialTemporal, and QuantitativeSpatialTemporal. They are involved in modifications of spatial modalities (cf. Paragraph 4.5.1.1.1). SequentialQuality defines modifications of entities.

4 Relations used for space

As described in Section 2, a configuration is said to *contain* entities that *participate* in it. This particular participation is identified in terms of relations between respective concepts. The full hierarchy of all relations that are part of the Generalized Upper Model 3.0 is given in Figure 1.2. In the following, necessary relation of spatial configurations are described.

4.1 domain

The relation domain is required for the concept Relating, as it defines one entity in this relating.

4.1.1 locatum

The object which is located in space in a spatial locating configuration. This term directly refers to the locatum in a linguistic sense, which is also called *origin*, as described in Levinson [2003].

4.2 range

range is the other required relation in a Relating. Both range and domain are integrated into the Generalized Upper Model 3.0 mostly for text generation reasons.

4.2.1 relatum

The relatum specifies the reference object that is referred to in a spatial locating configuration and holds between a place and a spatial object. Similar to locatum, this term is directly taken from linguistic classification of entities in spatial expressions Levinson [2003].

4.3 attribute

The relation attribute identifies the role played by a value in a configuration [Halliday and Matthiessen, 1999]. It specifies a particular character of an entity that takes part in a configuration.

4.3.1 direction

The direction relation indicates a directedness towards a place in a spatial configuration.

4.3.1.1 orientationDirection

An orientationDirection defines the direction of a re-orientation of an entity.

4.3.1.2 motionDirection

A motionDirection defines a re-direction in a directed motion configuration, i.e. only the direction of the motion and not the orientation of the entity changes.

4.3.2 placement

placement represents the relation in a configuration that describes the location, where something is or happens. It relates a Configuration to its SpatialLocating.

4.3.3 pathPlacement

A pathPlacement is used for a description of paths within motion configurations. GeneralizedRoutes can have pathPlacements, which are filled by GeneralizedPathLocations. They define the motion by elements that are represented in two- or three-dimension.

4.3.4 source

The relation source defines where a motion process has its starting point. It relates a GeneralizedRoute to a GeneralizedLocation.

4.3.5 destination

The relation destination specifies the endpoint of motion configurations, as it relates the GeneralizedRoute to its GeneralizedLocation.

4.3.6 pathIndication

The relation pathIndication defines a specific GeneralizedPathLocation in a GeneralizedRoute and it indicates the path of a motion by specifying an element that can be reduced to one-dimension.

4.3.7 route

A route can be part of a motion configuration and it is filled by a GeneralizedRoute.

4.3.8 nextPathPlacement

nextPathPlacement represents a composition of GeneralizedPathLocations, that forms a path out of a series of single paths. It defines the successor of one GeneralizedPathLocation, which is again a GeneralizedPathLocation.

4.3.9 nextPathIndication

nextPathIndication represents a composition of GeneralizedPathLocations, that forms a path out of a series of single pathIndications. It defines the successor of one GeneralizedPathLocation, which is again a GeneralizedPathLocation.

4.3.10 speakerAccessibility

The speakerAccessibility implies, that the speaker has access to the referred object, as expressed in "The seed is right here in the ground".

4.4 hasSpatialModality

The relation hasSpatialModality defines the spatial-functional relation of a GeneralizedLocation, as it relates a GeneralizedLocation to its SpatialModality.

4.5 circumstanceInConfiguration

This role relates a Configuration to a circumstance.

4.5.1 spatialTemporalCircumstance

spatialTemporalCircumstance represents all circumstantial spatial or temporal relations of any configuration.

4.5.1.1 spatialCircumstance

This relation is used to express modifications of spatial circumstances.

4.5.1.1.1 spatialExtent This relation expresses a spatial extent of a spatial circumstance. Subrelations of it are qualitativeSpatialExtent (e.g., "a bit") and quantitativeSpatialExtent (e.g., "for three miles"). The subrelations are further divided into qualitativeDistanceExtent, qualitativeAngleExtent, quantitativeDistanceExtent, and quantitativeAngleExtent. They define either distance or angular expressions.

Example 4.1: He moved a bit forward. (qualitativeDistanceExtent)

```
NonAffectingDirectedMotion 'nadm1'
      actor SimpleThing 'he' He
      processInConfiguration Process 'moving' moved
      motionDirection GeneralizedLocation 'gl1'
         relatum SimpleThing 'he'
         hasSpatialModality FrontProjectionExternal 'fpe1' forward
            qualitativeDistanceExtent QualitativeSpatialTemporal 'abit' a
bit
```

Example 4.2: She makes a semi-circle to the left. (qualitativeAngleExtent)

```
NonAffectingOrientationChange 'naoc1'
      actor SimpleThing 'she' She
      processInConfiguration Process 'making' makes
      orientationDirection GeneralizedLocation 'gl1'
         relatum SimpleThing -undefined-
         hasSpatialModality LeftProjectionExternal 'lpe1' to the left
            qualitativeAngleExtent QualitativeSpatialTemporal 'semi-circle'
a semi-circle
```

Example 4.3: He went one step down. (quantitativeDistanceExtent)

```
NonAffectingDirectedMotion 'nadm1'
      actor SimpleThing 'he' He
      processInConfiguration Process 'going' went
      motionDirection GeneralizedLocation 'gl1'
```

```
        relatum SimpleThing -undefined-
        hasSpatialModality SpecificDirectional 'sd1' down
          quantitativeDistanceExtent QuantitativeSpatialTemporal 'one-step'
one step
```

Example 4.4: She made a three-hundred-sixty degree turn. (quantitativeAngleExtent)

```
 NonAffectingOrientationChange 'naoc1'
      actor SimpleThing 'she' She
      processInConfiguration Process 'making' made
      orientationDirection GeneralizedLocation 'gl1'
        relatum SimpleThing -undefined-
        hasSpatialModality Surrounding 'sur1' turn
          quantitativeAngleExtent QuantitativeSpatialTemporal '360d' three-
hundred-sixty degree
```

4.5.2 generalizedMeans

A type of participant which can be agentive, manner, instrumental, or enablement. It is a generalized notion that refers to the abstract concept of the means for actualizing some process.

4.5.3 spatialPerspective

This relation defines the perspective towards the scene from where the spatial relation is described. Examples of such expressions are "from your point of view", "from my perspective". spatialPerspective is defined a GeneralizedLocation and filled by instances of SimpleThing.

4.6 hasModification

This relation relates an Element to its attributive modification. It occurs, for example, in spatial modifications of spatial relations.

4.6.1 hasEnhancement

This relation represents an enhancement of an element. In "They went diagonally through a working area", "diagonally" is an enhancement of "through".

Example 4.5: They went diagonally through a working area

```
NonAffectingDirectedMotion 'nadm1'
     actor SimpleThing 'they' They
     processInConfiguration Process 'going' went
     route GeneralizedRoute 'gr1'
          pathPlacement GeneralizedPathLocation 'gpl1'
               relatum SimpleThing 'area' the working area
               hasSpatialModality PathRepresentingInternal 'rpi1' through
                    hasEnhancement QualitativeSpatialTemporal 'qst1' diagonally
```

4.6.2 hasExtension

This relation represents an extension of an element. In "It is the right front box", "front" is an extension of "right". In most cases the second expression (front) extends the first one. In the expression "It is the right front wheel", "front wheel" could also be seen as a relatum in itself and the term "right" specifies its spatial modality (RightProjectionExternal).

Example 4.6: X is far down from Y.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'X' x
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing 'Y' y
          hasSpatialModality Distal 'd1' far
               hasSpatialModality BelowProjection 'bp1' down from
```

4.7 extremePosition

This relation describes an extreme position referring to distance, axis, etc.

4.7.1 extremeDistancePosition

This relation gives additional information about the relation between two entities of a SpatialModality. It describes their distance by implying an extreme position.

Example 4.7: The bowl is closest to the box.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'bowl' The bowl
```

```
processInConfiguration Process 'being' is
placement GeneralizedLocation 'gl1'
     relatum SimpleThing 'box' the box
     hasSpatialModality Proximal 'p1' close to
     extremeDistancePosition (true) closest
```

4.7.2 extremePositionOnAxis

This relation gives additional information about the position on an axis of an entity of a SpatialModality.

Example 4.8: The bowl is furthest to the left.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'bowl' The bowl
     processInConfiguration Process 'being' is
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing -undefined-
          hasSpatialModality LeftProjectionExternal 'lpe1' to the left
          extremePositionOnAxis (true) furthest
```

4.8 reciprocalRelation

The relation reciprocalRelation gives information about reciprocal relationships. It is typically expressed by "each other".

Example 4.9: The cubes are placed beneath each other.

```
SpatialLocating 'sl1'
     locatum SimpleThing 'cubes' The cubes
     processInConfiguration Process 'placing' are placed
     placement GeneralizedLocation 'gl1'
          relatum SimpleThing -undefined-
          hasSpatialModality BelowProjection 'bp1' beneath
          reciprocalRelation (true) each other
```

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