DESCRIPTION GRAMMARS: AN OVERVIEW

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Abstract. We present an overview of seventeen different accounts of the application of description grammars (or description functions), characterizing them according to their role in the grammatical design generation process and according to their representational specification. The objective and intended use of this overview is twofold: firstly as a referential overview of past precedents; secondly as a foundation to develop a formal representation for descriptions and description grammars.

Keywords. Shape grammars; description grammars; description; representation.

1. Introduction

“Designers work with descriptive devices of many kinds. These may be spatial or symbolic” (Stiny, 1991, p. 171). Descriptions may serve to compare designs to find similarities and dissimilarities. Descriptions may also be generated. Shape grammars have been used for both; they are a formal rewriting system for producing languages of shapes (Stiny, 1980). When we describe architecture, we are interested in both the description of the specific architectural object and its relation to other, similar architectural objects. Although shape grammars have been extensively used for this purpose, shape descriptions of architectural objects can be deficient. Stiny (1981, p. 257) noted that “main details of the functional elements comprising designs in these languages are provided in the informal, verbal descriptions of the shape [rewriting] rules used.” To address this deficiency, Stiny proposed to augment a shape grammar with a description function in order to construct the intended descriptions of designs. He illustrated the application of a description function with designs made up of blocks from Froebel's building gifts. However,
he indicated that the formal representation of descriptions, together with the
descriptions themselves, would "likely have to be worked out on a case-by-

Although Stiny references his 1981 article in quite a few subsequent arti-
cles, most references only touch upon the subject of shape descriptions, other
than visual descriptions, or, alternatively, extend on the subject of parallel
descriptions, – and grammars – a corollary of the description function. Only
once does Stiny (2006) revisit the topic with a new example, though he twice
(Stiny, 1987, p. 182; March and Stiny, 1985) alluded to a forthcoming paper
that would treat description schemes in more detail. More than thirty years
later, quite a few researchers have adopted the idea of a description function
or scheme, often specified as a description grammar, in conjunction with a
shape grammar, to qualify designs both spatially and descriptionally.

In order to at least attempt at presenting an exhaustive overview of the
application of description grammars, a citation search was conducted in
Google Scholar (114 entries), Web of Science (40 entries), ResearchGate (25
entries), and Microsoft Academic Search (18 entries) (the article was not
present in Scopus or CiteSeerX). Discarding duplicates and inaccuracies, a
total of 115 publications (and reports) referencing Stiny's paper was retained
for investigation. Five dissertations were retrieved and added, together with
three publications from personal resources. Out of this total of 123 publica-
tions, seven mistakenly include the reference (not referenced in the text) or
include it as part of a (wider) bibliography. Over one third (about 46) of the
publications include it as part of a literature review, but do not address the
topic of description schemes in the remainder of the publication. About an-
other 18 either address the topic of parallel grammars (without further em-
phasizing non-spatial descriptions), or consider descriptions in the form of
(spatial) topological, ontological or graph structures that require specific,
non-textual representational structures. These may warrant their own inves-
tigation, though such is outside of the scope of this paper. We will restrict
our investigation to descriptions that can be represented as strings, though
possibly manipulating numbers and lists. About another 14 publications
merely speculate on the adoption of a description scheme to augment a shape
grammar under consideration.

Out of the remaining publications, 37 (not including Stiny’s original pa-
per) include the specification and/or illustration of a description scheme.
These 37 publications refer to sixteen distinct accounts of description
schemes or their illustrations. We present all sixteen accounts here, next to
Stiny’s original account, characterizing them according to their role in the
grammatical design generation process and according to their representa-
tional specification. The objective and intended use of this overview is two-
fold: firstly as a systematic overview of past precedents to assist researchers who intend to create a description grammar themselves; secondly as a foundation to develop a formal representation for descriptions and description grammars, and an implementation of a description grammar interpreter for this formal representation.

2. Description schemes and their illustrations

We characterize all seventeen accounts according to their role in the grammatical design generation process and according to their representational specification. We identify four different roles for descriptions: as reflecting on the spatial elements and their composition, as expressing some property, such as volume, cost or manufacturing plan, as a design brief and as a generative guide (other than design brief). We classify the accounts according to their role.

2.1. DESCRIPTIONS AS REFLECTIONS

Stiny (1981) proposes a description function in order to construct the intended descriptions of designs. As such, these (textual) descriptions are derived from the generation process and do not impose any conditions on the respective shape descriptions. In his illustration of the description function as applied to designs made up of blocks from Froebel’s building gifts, the descriptions reflect on the spatial elements that constitute the design and the way these are combined.

Li (2001; also, 2004) applies a description function to the specification of a shape grammar for (teaching) the architectural style of the Yingzao fashi (Chinese building manual from 1103). The descriptions that are generated are taken from the annotated Yingzao fashi (Liang, 1983) and, similarly to Stiny’s (1981) illustration of description functions, the descriptions reflect on the composition of spatial elements that constitute the design. Li considers various descriptions (nine in total, specifying measures and descriptions of width, depth and height), as well as drawings (seven, from plan diagram to plan, section and elevation), in parallel.

Zamenopoulos (2012) considers the mathematical characterization of the organizational complexity of intentionality and proposes a category theoretic account of the semantic content of design intentionality, using descriptions of shape configurations to express interpretations of languages of designs.

All three accounts consider multiple descriptions, however, Stiny considers these descriptions to specify multiple sections within a single description, separated by the ‘#’ symbol. Description rules (Stiny uses the notation of a description rule to identify the changes applied by the description function to
an individual section) may reference the current value of other, parallel, descriptions (or sections), in the specification of the right-hand-side of the description rule. For example, having one description count the number of rafters, another description describes the disposition of the beams, including the resulting number of rafters (Li, 2001).

Stiny (1981) considers as sections descriptions integers, for counting, a coordinate pair, a sequence (of variable length) of coordinate pairs, sequences of tuples (of fixed length) of coordinate pairs, a sequence of sequences of coordinate pairs, and an adjacency matrix. Li (2001) considers as descriptions integers, real numbers (indicating lengths), tuples and sequences of integers, and triples of textual descriptions (strings). An append operation applies to sequences; operations of concatenation and replacement apply to strings. Zamenopoulos (2012) considers textual descriptions (enumerated terms or strings) and sequences thereof. Note that Zamenopoulos only exemplifies descriptions, not the underlying description rules.

2.2. DESCRIPTIONS AS EXPRESSIONS

A few authors consider description functions in the context of spatial grammars applied to mechanical engineering. These accounts invariably consider descriptions as expressing some property, such as volume, cost or manufacturing plan.

Brown et al (1996; also, Brown and Cagan, 1997) consider a description function that generates process plans for the manufacturing of objects manufacturable by a given process. The objects themselves are generated by a parametric attributed set grammar, but redefining the grammar instead as a shape grammar (with constraint specifications) would not impact the description function as such. Separately, Brown (1997) exemplifies volume calculation as a description function for a grammar specifying a language of stepped grooved shafts.

Agarwal (1999; also, Agarwal et al, 1999) considers a description function that yields cost expressions or equations that can be evaluated to reveal the cost of a design as the design develops through the generation process. This can be used to provide feedback on how design changes affect the cost and thus providing feedback on the generation process; but it can also be used to guide the generation process by cost preferences or constraints.

All three accounts consider description rules explicitly referencing the conjunctive shape rules. Whereas Stiny's (1981) description rules are specified as independent of the shape rules, Brown's (1997; and similarly, Brown et al, 1996) description rules for volume calculation require the conjunctive shape rule to provide values for the diameter and length of the section when
adding a new section to the shaft, and values for the diameter of the section and the width of the groove, when adding a circumferential groove to a section of the shaft. While Agarwal's (1999) cost equations make explicit reference to characteristics of the shape under rule application, such as its dimensions, these are not evaluated during rule application. However, in order to provide feedback on how design changes affect the cost during the generation process, the cost equations must be able to be evaluated on the corresponding shape at any time.

Brown et al (1996) consider operations to retrieve the first element or elements from a sequence and to prepend one or more elements to a sequence, using a shorthand notation borrowed from logic programming. Additionally, they consider a function to reverse a list, so as to allow the list to be operated upon from the back as well. They also consider functions as part of description rules that are specific to the grammar under consideration. While these functions are themselves expressed as description rules, they do not necessarily operate on the same or similar descriptions.

2.3. DESCRIPTIONS AS DESIGN BRIEF

Duarte (2001; also, 2005a) considers a discursive grammar to incorporate a shape grammar, a description grammar and a set of heuristics, at least from a technical viewpoint. The use of heuristics is intended to constrain the rules that are applicable at each step of the design generation. From an operational viewpoint, a discursive grammar combines a programming grammar generating design briefs based on user and site data and a designing grammar using the design brief(s) to generate designs in a particular style. Both programming grammars and designing grammars utilize description grammars, though only the designing grammar complements the description grammar with a shape grammar. Duarte and colleagues apply discursive grammars to the Portuguese housing program guidelines and evaluation system (PAHP) and the houses designed by the architect Alvaro Siza at Malagueira (Duarte, 2001), to urban design (Beirão, 2012) and to housing rehabilitation (Eloy, 2102; also, Eloy and Duarte, forthcoming). Duarte (2005b; also, 2001) presents the Malagueira grammar, separately, as a designing grammar only. Here, descriptions represent functional zones and their adjacency relations.

Descriptions, in these applications, take various forms. All accounts consider sequences and tuples of various kinds, in parallel descriptions, considering tuples, sequences, and nested variations thereof, of various types, including mixtures of numbers, terms (enumerations and strings) and tuples/sequences. Enumerations of terms denote, for example, functions, spaces, qualifications, rule labels, ontological terms, etc. Distinct from
strings, enumerated terms are fixed — though a description rule may replace one term by another —, and they always form separate entities in a tuple when collected in a description. While almost all enumerations are grammar-specific, Duarte (2001) also proposes an enumeration of 'true' and 'false'.

While Brown et al (1996) consider a set notation, their set is in other ways indistinguishable from a variable-length list. Duarte (2005b), on the other hand, uses sets for their ability to identify and remove individual elements from a set without having to be concerned with the size of the set, or the ordering of the elements in the set, in the specification of the description. Eloy (2012) uses a variable-length list notation in the abstract specification of the various, parallel, descriptions, but omits the list and identifies only the individual elements of concern in the specific description rules, as in the case of a set. Duarte (2001) considers tables as fixed descriptions, containing dimensional and cost information. Here too, each table can be represented as a set, of triples, where each triple specifies the row and column indices and the corresponding cell value.

Duarte (2001), Beirão (2012) and Eloy (2012), as well as Li (2001), all consider conditional specifications that additionally constrain rule application and cannot simply be captured in an explication of the left-hand side of the rule. For instance, a rule may apply in a number of different cases that correspond to different values for a single description entity. Short of specifying different rules corresponding the different values, which could work in the case of an enumeration but would fail in the case of a real numeric interval, conditional specifications may allow a parameter to be constrained beyond a single value. Duarte (2001), Beirão (2012) and Eloy (2012) all use constraints that limit parameter values to a given set of (enumerated) values. Li (2001) and Eloy (2012) also consider numerical conditions constraining a numeric value in function of other numeric values that are part of the same description. Note that Brown et al. (1996) also consider rule variants that include conditional specifications but these can easily be captured in a further explication of the left-hand side of the rule.

Li (2001), Duarte (2001; 2005b), Beirão (2012) and Eloy (2012) allow rules to request or necessitate user input. Specifically, Li (2001) and Beirão (2012) identify a series of variables for input by the user, the input for which can be provided beforehand or, if missing, at rule application. In the case of Duarte (2001; 2005b) and Eloy (2012), however, the same rule might be applied more than once with different input values, therefore necessitating user input at rule application.
2.4. DESCRIBITIONS AS GENERATIVE GUIDE

Many other accounts consider descriptions as generative guide, other than design briefs.

Knight (2003) proposes state descriptions to guide an optimization process. A compound shape/description rule specifies a fitness function that computes the state description from the shape under consideration. The actual shape is left unchanged in the application of this rule. Only if the resulting state description is, e.g., 1, another (compound) shape rule will consequently modify the shape. Unlike Brown at al (1996) and Brown (1997), these (state) descriptions reference the actual shape under rule application, rather than simply the conjunctive shape rule.

Knight (2003) also proposes functions encoding algorithms to be embedded in description rules. Liew (2004) proposes a number of “descriptors” to guide the rule application process, one of which considers an application of Knight’s description scheme using functions that encode algorithms applying to the shape under consideration (under rule application). Another descriptor is also specified as a description scheme; this one considers a description that specifies a set of rules (or references thereof); rules apply only if the rule reference is present in the current description.

Stiny (2006) presents description rules for Palladian villa plans that count the number of rooms and assign plans to equivalence classes, and explores the use of such descriptions to set goals to guide and control the design process. Ahmad (2009; also, Ahmad and Chase, 2006) proposes to augment a shape grammar with a style description scheme based on the concept of semantic differential to map the style characteristics of shape rules. While these style descriptions do not guide the generative process, instead, they do serve to guide the grammar transformation process for the purpose of stylistic change.

Al-kazzaz (2011; also, Al-kazzaz et al, 2010) considers descriptions in shape grammars for hybrid design, where the descriptions provide feedback on rule application based on comparisons between the generated design and the antecedents in the corpus. Additionally he considers a user guide specified as sets of antecedent labels. Muslimin (2013) uses descriptions to investigate how meaning is embedded in the Passura’ carvings of the Toraja people in South Sulawesi, Indonesia. He exemplifies the descriptions both as a result of the shape generation and as a guide to the shape generation.

Finally, Stouffs and Tunçer (forthcoming) consider a description scheme in the context of the generation of historical architectural typologies, generating an instance of the typology of classical period Ottoman mosques of the architect Sinan from an ontological description thereof.
Knight (2003) and Liew (2004) suggest for descriptions to include custom functions that apply to the shape under rule application. Ahmad (2009), Al-kazzaz (2011), Muslimin (2013) and Stouffs and Tunçer (forthcoming) all consider enumerations of terms. Ahmad (2009) and Muslimin (2013) consider structured lists of various kinds. Both Al-kazzaz (2011) and Stouffs and Tunçer (forthcoming) make use of sets. Similar to Li (2001), Stouffs and Tunçer consider textual descriptions that can be represented as strings with operations of concatenation and replacement. While Li considers as a description a triple of strings, each describing a specific aspect, that together form a single statement about the building style, Stouffs and Tunçer consider an ontological description in the XML format represented as a single string that is built up through description rules. Both description schemes necessitate the ability to parameterize parts of the string and rebuild the string from these parts and additional, explicit writing.

4. Towards a formal representation for descriptions and description grammars

The maximal element representation (Krishnamurti, 1992) is a formal representation for shapes in support of shape grammars, specifying a shape as a collection of maximal (spatial) elements, each represented by a pair composed of a co-descriptor and a boundary. The co-descriptor describes the infinite carrier of the element of the same dimension (the carrier of a point is the point itself), the boundary is expressed as a shape of maximal elements of a lower dimension (e.g., points in the case of a line segment, a point has no boundary). The maximal element representation is a canonical representation that captures the notion of emergence: any part of a shape is a shape and can be recognized as such.

A formal representation for descriptions, similarly, should allow for the matching of descriptions. However, while recognizing a shape as part of another shape relies on a partial order relation on maximal elements, there is no partial order relation for descriptions, unless these are defined as sets. Instead, we define a matching relation between a parametric description that is the left-hand-side of a description rule and a non-parametric target description. A potential match assigns values to the parameters within the parametric description. Different from shapes, a formal representation for descriptions can be defined at two levels: as a textual description that is both human and machine readable, and as a structured representation that better supports the matching of descriptions.

Stouffs (2014) presents a generalized specification for descriptions in textual form that includes numbers, strings, lists and sets (of descriptions), vari-
ous operators and functions as well as parameters. More work is required to include references, user input values, custom functions, etc. Additionally, a tree structure is proposed to support the computational matching of descriptions.

5. Conclusion

We have presented seventeen different accounts of the application of description grammars (or description functions), classifying them according to their role in the grammatical design generation process and, additionally, characterizing them according to their representational specification. These seventeen accounts present an extensive overview of specifications and/or illustrations of description schemes, as originally proposed by Stiny (1981). They form the sources of reference for a continued development of a formal, generalized representation of descriptions that, if not all, will support a significant number of the variations in descriptions and description rules offered in these schemes. They may also serve the reader as a source of inspiration for the creation of new description grammars. The development of a description grammar interpreter that supports the proposed formal representation as part of a shape grammar interpreter is in progress, in order to facilitate the exploration, development and implementation of description grammars.

References


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