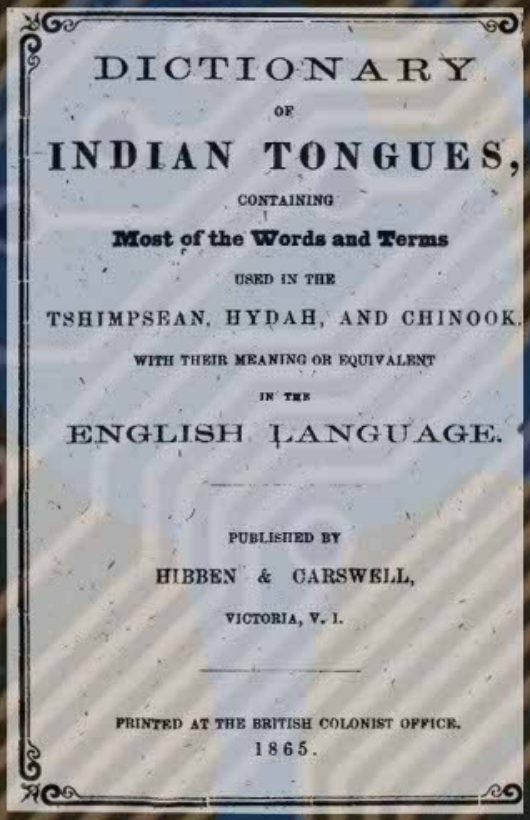
Language Documentation & Conservation Special Publication No. 4

Electronic Grammaticography


DICTIONARY
OF
INDIAN TONGUES,
CONTAINING
Most of the Words and Terms
USED IN THE
TSHIMPSEAN, HYDAH, AND CHINOOK
WITH THEIR MEANING OR EQUIVALENT
IN THE
ENGLISH LANGUAGE.

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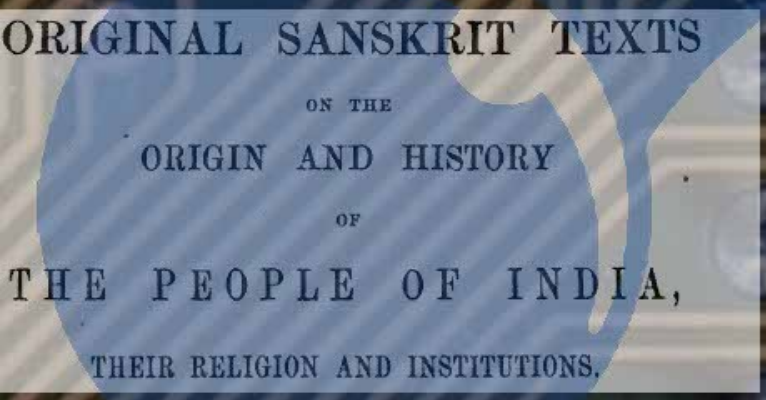
ORIGINAL SANSKRIT TEXTS
ON THE
ORIGIN AND HISTORY
OF
THE PEOPLE OF INDIA,
THEIR RELIGION AND INSTITUTIONS.

edited by Sebastian Nordhoff

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Contents

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Part I.

Theory

1

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Deconstructing descriptive grammars

Jeff Good
University of Buffalo

Much work within digital linguistics has focused on the problem of developing concrete methods and general principles for encoding data structures designed for non-digital media into digital formats. This work has been successful enough that the field is now in a position to move past "retrofitting" digital solutions onto analog structures and to consider how new technologies should actually change linguistic practice. The domain of grammaticography is looked at from this perspective, and a traditional descriptive grammar is reconceptualized as a database of linked data, in principle curated from distinct sources. Among the consequences of such a reconceptualization is the potential loss of two valued features of traditional descriptive grammars, here termed *coverage* and *coherence*. The nature of these features is examined in order to determine how they can be integrated into a linked data model of digital descriptive grammars, thereby allowing us to benefit from new technology without losing important features intrinsic to the structure of the traditional version of the resource.

1 From recoding to reconceptualizing The field of linguistics is now well aware of the need to use new digital technologies to encode linguistic data with care in order to ensure its portability across user communities, computational environments, and even time (Bird & Simons 2003).[1] This has resulted in a range of work examining the best means through which traditional linguistic resources can be re-encoded in digital form. Proposals have been made, for instance, that offer conceptual models and accompanying digital implementations for lexical resources (Bell & Bird 2000, Poornima & Good 2010), interlinear glossed text (Bow et al. 2003, Schroeter & Thieberger 2006, Palmer & Erk 2007), grammatical paradigms (Penton et al. 2004), and descriptive grammars (Good 2004) (see also Drude (this volume) and Musgrave & Thieberger (this volume)). Other work has gone beyond this to codify general principles for conducting this kind of research, as seen, for instance, in Nordhoff's (2008) examination of possible ideal requirements for electronic grammars and

[1] I would like to thank audience members at the Colloquium on Electronic Grammaticography, held at the Second International Conference on Language Documentation and Conservation at the University of Hawai'i at Mānoa, February 11–13, 2011, as well an anonymous reviewer, for their comments on the work leading to this paper. Many of the ideas developed here have been influenced by informal discussions with a number of individuals during the last several years, in particular Michael Cysouw and Sebastian Nordhoff.

in the "meta-model" approach to lexical encoding embodied by Lexical Markup Framework, developed in the context of work on natural language processing (Francopoulo et al. 2009) (see also Wittenburg et al. (2002) and Trippel (2006, 2009)).

This work has produced important results, and, in particular, has made clear that, even if important kinds of linguistic data may still await proper study, the challenges of encoding them linguistically are presumably solvable using existing technologies, in particular generalized markup systems like XML (see Good (2011:225–227) for discussion of XML in the context of language documentation). Furthermore, it is even possible to extract from this body of research an informal general procedure for devising new encoding schemes: (i) survey existing practice for presenting data in a given domain, (ii) devise a conceptual model of the data that can be understood as providing an underlying form for the surveyed presentation (or "surface") forms, (iii) relate the various components of that model to linguistic practice, focusing, in particular, on how they can be derived from more general principles regarding what constitutes appropriate methodology for linguistic analysis, and (iv) propose a concrete way of encoding that model using archival markup formats that is as consistent with those general methodological principles as possible. While I am not aware of any one publication that incorporates the totality of these procedures, the combination of Good (2004) and Nordhoff (2008) can be understood as an illustration of this approach in the domain of descriptive grammars (see also Nordhoff (this volume)).

At the same time, the sensible reliance of such work on *existing* practice makes it ill-suited for considering the ways in which new technologies should prompt more fundamental reconceptualizations of the kinds of products that the field of linguistics should produce as a result of technological changes. This is illustrated, for instance, by Palmer & Erk's (2007) revision to Bow et al.'s (2003) proposals for encoding interlinear glossed text. The latter is sufficient for dealing with interlinear glossed text's traditional function of providing a succinct analysis of the lexical and grammatical content of a given stretch of phrasal data. However, it is not well-suited for an additional function that is clearly desirable (though non-traditional): automated (or semi-automated) annotation.

The main goal of this paper is to consider how new models for data encoding—developed independently from the field of linguistics—might prompt us to consider revisions to our models for producing traditional grammatical descriptions. In particular, detailed consideration will be given regarding how the work required to describe a language's grammar on the basis of documentary products might be done in a highly distributed fashion by making use of emerging Web technologies (sections 2 and 3). However, as we will see, there is a danger when considering such a possibility: The introduction of a new conceptualization of a linguistic resource, with clear positive features, may inadvertently lead to the loss of valued features embedded within traditional models. This requires the development of means to reintegrate what has been "lost" into the new conceptualization, which can be done by augmenting received technologies with solutions more specific to linguistics (sections 4 and 5). However, the solutions discussed here only allow us to retain part of what would be lost, underscoring that the transition from traditional products to digital ones must be led by linguists' needs rather than the non-linguistic agendas that drive the development of most new technologies (section 6).

This paper is primarily conceptual in nature, rather than reporting on the results of a specific technological implementation. Accordingly, at times, it will be somewhat speculative,

though an attempt will be made, whenever possible, to ground any speculation in relevant existing technological efforts, often from within linguistics itself. The intended audience for this paper are so-called ordinary working linguists, rather than those more directly engaged in applying emerging technologies to linguistic work. At the same time, I hope that some of its key ideas will be of interest to both groups. Those familiar with work on the technologies to be discussed will be aware of the fact that some of the points made here are relatively well-known outside of linguistics. Therefore, in some places, the aim of the discussion will not be to outline the significance of these new technologies generally but, rather, to present them in a way that makes their utility clearer to a documentary and descriptive linguistic audience—that is, to linguists who are now, or may in the future, be creating new grammatical descriptions.

2 The technological context While some data encoding technologies (e.g., XML) have become so ubiquitous in work on language documentation and description as to require little introduction, the technological context which inspires the present work—that of the so-called Semantic Web—has not yet been particularly widely employed within linguistics. The leading idea behind the development of the Semantic Web is to extend the document-centered World Wide Web to all kinds of data, adding, in effect, an explicit layer of meaning to a network architecture that was originally designed to simply link together pages intended to be interpreted by humans.[2]

Rather than consisting of a monolithic piece of technology, the Semantic Web is better understood as resulting from the interactions of a set of logically-independent technological pieces. Some of these are relatively simple in and of themselves but, nevertheless, provide crucial elements of the infrastructure needed to augment the World Wide Web with semantic information. Moreover, since the Semantic Web is intended to build on the World Wide Web, many of its core technologies are the same as those of the World Wide Web itself, as seen, for example, in its use of Unicode for character encoding (see, e.g., Anderson (2003) and Gippert (2006:345–351) for discussion of Unicode in a linguistic context). At the same time, in order to extend the World Wide Web, there are also technologies that underlie the Semantic Web that are not part of the World Wide Web. The most prominent of these within work on language documentation and description is almost certainly Web Ontology Language (OWL), which has been used to express the linguistic information encoded in the General Ontology for Linguistic Description (GOLD) (Farrar & Langendoen 2003, Farrar & Lewis 2007, Farrar & Langendoen 2009).[3] GOLD will be returned to shortly below.

The Semantic Web technologies that will play a significant role in the discussion here are given in table 1. (The first of these, the URI, is also a World Wide Web technology and likely to be familiar to many readers.) A brief summary of the relevant function that each takes on is included in the table, though this description should not be understood to be exhaustive in a general Semantic Web context. Both in the table, and elsewhere, the presentation of the Semantic Web and relevant component technologies is simplified somewhat for the purposes of exposition.

[2] The Semantic Web Frequently Asked Questions page (http://www.w3.org/2001/sw/SW-FAQ) produced by the World Wide Web Consortium serves as useful introduction to the Semantic Web. See also Chiarcos et al. (2012a:2–5) and Moran (2012:129–131) for additional introductory discussions in a linguistic context.

[3] The latest version of GOLD can be viewed at http://linguistics-ontology.org/.

ACRONYM	TECHNOLOGY	FUNCTION
URI	Uniform Resource Identifier	Unique identification of entities
RDF	Resource Description Framework	Description of entities
OWL	Web Ontology Language	Encoding of general facts

TABLE 1.: Some Semantic Web Technologies

Taken together the three technologies listed in table 1 allow for (i) the unique reference to anything in the real or mental world (e.g., a language, an utterance, or a phoneme) in the form of URIs, (ii) the specification of "facts" about those entities (e.g., *English is a language* or *this sentence makes use of a passive construction*) in the form of RDF expressions, and (iii) the specification of the overall properties of the conceptual model that the entities and facts are embedded within (e.g., *sentences have grammatical properties* or *lexical items are comprised of a combination of sound, meaning, and grammatical properties*) in the form of OWL statements. While the ability to specify such information falls short of the rich content of a traditional descriptive grammar, it should be clear that even this relatively minimal apparatus could allow for the production of a significant amount of description of a given language's grammar. In particular, it would permit many of the "low-level" facts that are part of any complete grammatical description to be encoded in a machine-readable form on the Web.

It would be inappropriate to cover the full technical details of URIs, RDF, or OWL here. However, it will be useful if something can be said about what these technologies "look like" in concrete terms, especially since none of them is a prototypical instance of a "technology". In Semantic Web applications, URIs look more or less like the familiar Uniform Resource Locators (URLs) associated with web pages, taking on a form like `http://example.org/English`. URLs can, in fact, be understood as a type of URI that both identifies a given entity (e.g., a web page or a file) and also specifies how the entity can be found on the World Wide Web. While Semantic Web URIs look like URLs, and may even behave like URLs in resolving to a web page when accessed on a browser, strictly speaking they need not be URLs. In concrete terms, this would mean that if a URI, which was not also a URL, were entered into a browser, it would not resolve to any web page (and produce, for example, an error page).

The idea that a URI may look like URL, but not act like one, is potentially counterintuitive to those accustomed to working with the World Wide Web rather than the Semantic Web. However, it is a reasonable consequence of attempting to build an online repository of information on top of the existing Web rather than in a completely new environment. In this case, the standard Web mechanism for uniquely referring to a given web page is simply extended for uniquely referring to *anything*, whether or not it happens to be associated with a web page. Of course, alternatives are possible. For instance, the Handle System provides another mechanism for creating unique identifiers (see Broeder et al. (2006) for discussion of the use of the Handle System in developing linguistic infrastructure).[4]

[4] The Handle System is used by this journal as a means of persistent identification for published papers. For example, the handle for Newman (2007) is 10125/1724. This handle can be resolved, using an appropriate online service, to a web page where a copy of the paper can be found. One way to do this is to simply append the handle to http://hdl.handle.net/, producing the URL http://hdl.handle.net/10125/1724.

An important feature of URIs is that they are not merely unique within some local system, as might be the case, for instance, for identification numbers of the sort commonly associated with records in a database. Rather, they are universally unique in the context of the Web, at least when used as intended. That is, in Semantic Web terms, anything that needs to be referred to gets a completely unique identifier. The vast proliferation of identifiers that this entails may, at first, sound problematic. However, one must bear in mind that the World Wide Web has grown vastly since its first inception without breaking down, illustrating the durability of URIs as a mechanism for providing globally unique references.

Turning now to the second technology listed in table 1, Resource Description Framework (RDF) is a means for making machine-readable three-part statements, or *triples*, of the form SUBJECT PREDICATE OBJECT. The subject is a URI for some entity, the predicate is a URI for a possible relationship between a subject and an object, and the object consists of either of a URI or a limited class other objects, such as a text string. Figure 1 gives an example of a representation of two RDF triples. The first (Triple 1) is intended to relate a subject URI referring to the English language to an object URI referring to the phoneme *p* via a predicate that states that that phoneme is found in English (i.e., "English has the phoneme *p*"). The second (Triple 2) relates the phoneme *p*, now serving as a subject of a triple, to its standard transcription, the text string "p", serving as the object of the triple (i.e, "The phoneme *p* has the transcription 'p'").

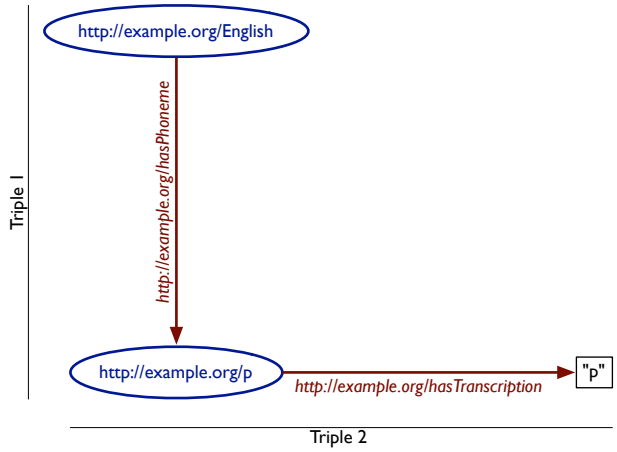

FIGURE 1.: Two RDF triples

RDF has not yet been widely deployed for describing traditional linguistic data, though there have been some attempts, both as exemplary cases (Simons 2005) and in working systems (Good & Hendryx-Parker 2006) (see also Cysouw (2007:63–65)).[5] It has also seen attention in research in computational linguistics (see, e.g., Ide et al. (2003)).

The information encoding model of RDF is, in principle, expressible in a variety of formats, including a standardized XML format, which facilitates exchange of data described in

[5] The websites for the World Atlas of Language Structures (WALS) (Dryer & Haspelmath 2011), the World Loanword Database (Haspelmath & Tadmor 2009), and Glottolog/Langdoc (Nordhoff 2012) all allow data to be exported in RDF format, though in the case of WALS, this is limited to bibliographical data.

RDF. More generally, RDF can be understood as a means for encoding data that can usefully be modeled in the form of a graph consisting of nodes connected by labeled arcs, as is seen in figure 1.[6] Of course, RDF is not the only way of describing data in graph form, though it is the focus here because of its role as a key means of expressing "atomic" statements about entities in the context of the Semantic Web.[7]

An important feature of graphs (whether or not they are expressed in RDF) is that, as discussed by Ide & Suderman (2007), they facilitate the merging of information from distinct sources. As long as two related sets of data expressed in graph form use the same identifiers for nodes referring to the same entities, the two graphs can simply be joined wherever nodes are shared. If we consider figure 1, for instance, one data source could state that English makes use of the phoneme *p*, while another could associate *p* with a transcription, with the two being joined by their common node, http://example.org/p. While this is a relatively trivial example, graph merger of this kind can become quite powerful when the merged graphs each contain rich and largely complementary information (see section 3.1).

URIs and RDF, when brought together, are key pieces to the idea of creating significant amounts of *Linked Data*, which is seen as a crucial step towards the broader vision of the Semantic Web (Bizer et al. 2009:15) and provides a useful metaphor for understanding the goals of the Semantic Web more generally.[8]

The final technology listed in table 1 is Web Ontology Language (OWL), which allows for the expression of *ontologies*. In this context an ontology can be understood as a means for expressing general knowledge about a given domain in a form that can be understood by machines. This might include statements like, *a past tense is a kind of tense* or *a phoneme inventory is comprised of phonemes*. Basic statements like these could, in fact, be stated using RDF which is flexible enough to encode both very specific statements as well as general ones. OWL, however, provides a means for expressing certain kinds of generalizations that are not standardly expressible in RDF. In fact, OWL can itself be viewed as an augmentation of RDF in much the same way as the Semantic Web augments the World Wide Web. To pick one example, OWL provides a standard way of stating that one property is the "inverse" of another property. This would allow, for instance, a machine to infer that, if *the phoneme* p *has the transcription 'p'*, then *the symbol 'p' is a possible transcription of the phoneme* p. As discussed above, there has already been significant work on an OWL-based ontology in the context of descriptive linguistics in the form of the GOLD project (Farrar & Langendoen 2003, Farrar & Lewis 2007, Farrar & Langendoen 2009), and there has also been work using OWL to support the mobilization of descriptive language materials (Beck et al. 2007).

Before moving on, it is important to bear in mind that URIs, RDF, and OWL are merely specific technical solutions to more general problems. Their significance in the present

[6] The fact that the connections between nodes in RDF representations can be labeled or "typed" makes them richer than the connections found in typical hypertext which merely links documents (or parts of documents) without specifying the semantic nature of those links. Therefore, while "hypertext grammars" (Evans & Dench 2006:29) would clearly represent an advance over traditional grammars, they would fall short of the possibilities afforded by the Semantic Web.

[7] Another common way of expressing graphs with labeled arcs in linguistic work is through the use of feature structures as found, for example, in Head-driven Phrase Structure Grammar (Sag et al. 2003:50–51).

[8] A workshop on Linked Data in Linguistics was held on March 7-9, 2012, in Frankfurt, Germany (see http://ldl2012.lod2.eu/) and resulted in an edited volume (Chiarcos et al. 2012b).

context is the way that they are integrated into the larger vision of the Semantic Web. Of course, the Semantic Web, too, is a specific technical solution to the broad problem of how information can be shared and exchanged efficiently. Its relevance for the field of linguistics is twofold. First, it offers a model for a new way of managing research results in an increasingly internet-driven data management world. Second, it is a specific instantiation of such a model with considerable support outside of linguistics, allowing linguists to take advantage of technological infrastructure that has already been developed elsewhere.

The next section of this paper will consider how an initiative like the Semantic Web might prompt us to reconsider what it means to create a descriptive grammar of a language.

3 Multiple facets of grammars

3.1 Disentangling publication In this section, I will largely abstract away from the technical details delineated in section 2 and, instead, focus on how the model embodied by the conjunction of the technologies in table 1 could be exploited to create new methods for producing grammatical descriptions. In principle, a number of the ideas developed here could have been put forth decades ago. After all, many of the key concepts embodied by the Semantic Web (e.g., unique identification) are hardly new. However, in practice, before the rise of the World Wide Web, work along such lines would have been largely impossible to apply concretely to documentary and descriptive research. We have now reached a point, by contrast, where the development of models that, at one point, would have been merely speculative or "futuristic" can actually be implemented in specific tools, at least in prototype form. This makes it important for the field to begin to consider the relevant issues proactively in order to avoid accidentally adopting technological solutions that might, at first, appear to be appropriate but which may actually be built on assumptions that will prove problematic in the long run. (See Boynton et al. (2010:134–138) for relevant discussion in a language documentation context.)

A striking feature of the model that the Semantic Web offers is the extent to which it leads to a view of scholarly work in general, and grammaticography more specifically, wherein a number of elements that were previously intertwined due to the restrictions of paper publication can now be decoupled from one another. Based on ideas found in Neylon (2010), we can break down the functions of traditional "monolithic" scholarly publications along the lines of what is described in the following list.

1. **Registering:** Scholarly publishing allows an individual or set of individuals to officially establish that they should be associated with a given set of ideas or research results.
2. **Filtering:** Scholarly publishing provides mechanisms through which a given user can locate the information they are interested in both by providing a means through which the quality of a given piece of research can be quickly assessed and by providing tools for discovery (e.g., through the use of keywords).
3. **Curation:** Scholarly publishing works with carefully aggregated sets of data that are brought together to tell a specific "story".
4. **Archiving:** Scholarly publishing produces resources designed to be usable in the long-term.

5. **Reusing:** Scholarly publishing is associated with standardized mechanisms through which research results can be reused in a manner deemed acceptable by the research community (e.g., by providing a stable citation for a given resource).

Of the five functions of publishing given above, the one of greatest interest here—and the one which would would seem to be most profoundly impacted by the technologies discussed in section 2—is almost certainly the curatorial function. The traditional model of a descriptive grammar as a kind of monograph encourages us to see the thousands of tiny observations that form a complete description as part of a single research "outcome". The graph-based model of the Semantic Web, by contrast, explicitly makes each of these observations visible as distinctive connections among discrete objects. This was already schematized in figure 1, with a relatively simplistic example. Figure 2 offers something comparable with a more complex example that abstracts away from some of the more technical aspects of RDF.

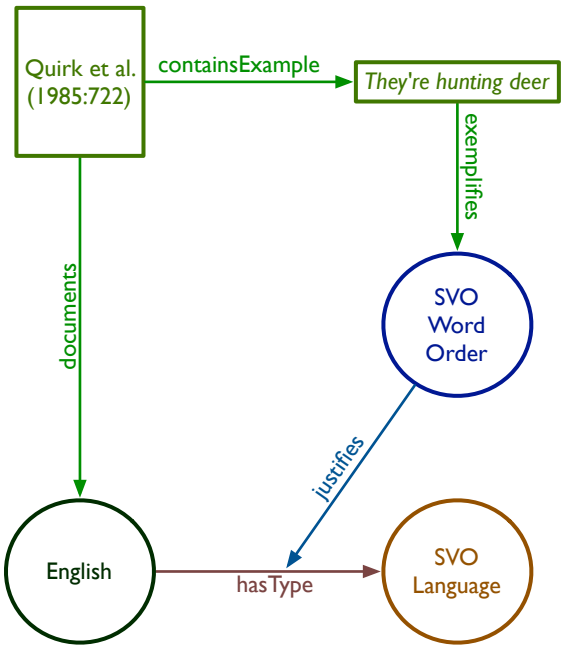

FIGURE 2.: A fragment of a descriptive grammar in graph form

Figure 2 represents a set of low-level statements which, when combined, allow one to make a claim like *English is an SVO language*. At the top of the figure, an example is indicated as being extracted from a source that documents the English language. This example is observed to show SVO word order, which, in turn, justifies the general classification of English as an SVO language. In RDF terms, this would mean breaking down the classification of English as SVO into five distinct statements (or triples). There are obvious elements of simplification involved in the figure, though it should be sufficient for purposes of exemplification.

By way of further illustration, figure 3 represents further information about one of the nodes in figure 2, the one representing the English language. This figure gives reference information for English, specifically a language code and its genealogical parent. It can be understood here as representing information about the same entity as described in figure 2, but coming from a different source.

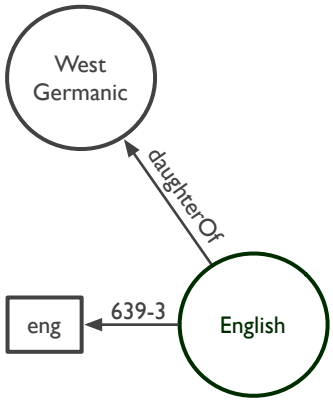

FIGURE 3.: Classificatory information for English in graph form

Figure 4 illustrates one of the positive features of graph-based representations of information (see also section 2): The fact that they allow information from different sources to be straightforwardly merged as long as common node identifiers are employed. In figure 4, the content of figures 2 and 3 are brought together into a single graph.

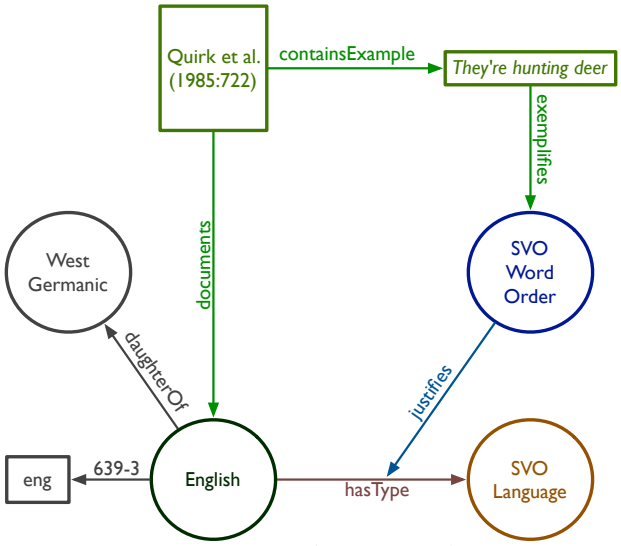

FIGURE 4.: Merging two graphs

Of course, there is nothing particularly innovative about combining related pieces of information from distinct sources. The power of graph-based representations like the one seen in figure 4 is the way in which they allow this process to be, at least partly, automated and the way in which they make visible the nature of the connections between data sources in a more precise way than is possible with standard academic citations.

This latter point is of interest here when we consider the inherently "distributed" task of writing a descriptive grammar—even if it is only written by a single author. They are typically the distillation of a number of years, or even decades, of work on a language and untold numbers of small observations, preliminary analyses, reanalyses, etc. (see Weber (2006:417–418) for relevant discussion). Moreover, the distributed nature of the work involved in grammar writing has become significantly more pronounced in recent years with the rise of the documentary paradigm. This has stressed methodological and theoretical separation between research outputs that can be classified as "documentary" from those that are "descriptive" (Himmelmann 1998; Woodbury 2011:168–169). The next section will consider then what a "graph-based" approach to data might mean for grammar writing, especially in the context of the newly placed emphasis on documentation. A more concrete way of looking at this issue would be to ask: How would grammar creation be different if crafting each of the component statements of a classification like the one represented in figure 2 was the responsibility of different linguists?

Before moving on, it seems worth emphasizing that many of the issues to be addressed below—for example, ensuring that a grammar has adequate coverage or that its analyses are coherent—existed long before the development of digital approaches to research. What has changed is that, now that research can, in principle, be done in a much more distributed fashion, the utility of general solutions to problems like these has become more apparent. In the creation of single-authored grammars, the main control on coherence, for example, has been the authors themselves. But clearly this concern must be approached differently if one wants to make use of the time and the skills of ten, or even a hundred, contributors working on the description of a single language. Moreover, as we will see in the next section, there has been impetus for grammatical descriptions to be developed in a more distributed fashion that has arisen completely independently from the growth of the Semantic Web itself.

3.2 **Towards distributed grammar authoring** The extent to which the activities comprising documentation and description should be viewed as easily severable has been questioned (see, e.g, Evans (2008:346–348)). Nevertheless, it seems uncontroversial that the possibilities that new technologies offer for creating documentary products should have a significant impact on the creation of grammatical descriptions (Evans & Dench (2006:24–25), see also Good (2010:120–122)). Moreover, the documentary paradigm has emphasized the need for a more collaborative approach to the collection and analysis of language data, integrating members of speaker communities, as well as experts from allied disciplines, more directly into the linguist's research activities (Himmelmann 2006:15–16; Dwyer 2006:54–55; Grenoble 2010:293–399; Woodbury 2011:176–177).

While not always emanating from the same fundamental concerns, both of these ideas share a comparable impact when it comes to research which has as one of its goals the production of a descriptive grammar. On the one hand, new data collection and annotation technologies have led to an emphasis on ensuring that the provenance of a descriptive

claim can be straightforwardly verified by associating it with the relevant supporting documentary materials. Ideally, these should be in the form of fully transcribed texts as well as audio and video records (see, e.g., Bird & Simons (2003:571); Nordhoff (2008:299); Thieberger (2009)). This requires tools and methods for making the "documentary chain" from recording to analysis explicit, which amounts to creating a new set of intermediate linguistic resources comprising each of the relevant links in that chain. A prominent example of this is time-aligned annotation, which connects a transcription directly to the recording containing what is being transcribed. This has resulted in the widespread use of a relatively new kind of linguistic resource which encodes documentary and descriptive annotations (see Schultze-Berndt (2006) and Bouda & Helmbrecht (this volume)) directly with an indication of start and end times within a media file that those annotations can be associated with. This is found, for example, in resources produced by the ELAN annotation tool (see Berez (2007) for a review). What we see in this case is that the task of annotation, which formerly was disseminated primarily as embedded within finished products, can now be associated with an "intermediate" resource reflecting an important aspect of the underlying work.[9]

On the other hand, collaborative models for collecting and analyzing linguistic data cause us to shift perspective from an approach where a single individual is responsible for all stages of grammatical analysis to one where the various stages of the documentary and descriptive workflow might be the primary responsibility of different contributors (see, e.g., Thieberger (2004) and Bowern (2011:461–462) for discussions of workflow). This adds an additional element of "decomposition" to the traditional way of working. In large part, new data management and communication technologies are a prerequisite to the practical application of such collaborative models. However, their ultimate motivation is largely social in nature and emanates from changes in the conception of what constitutes ethical and appropriate research practices (see, e.g., Rice (2006a:124–134) and Dobrin & Berson (2011:201–206)). They can also be understood as a response to language endangerment, insofar as the impending loss of a language is understood as a loss not only to linguistics, but to speaker communities and other disciplines as well. This has, thereby, caused linguists to seriously consider the need for approaches incorporating a diverse array of stakeholders in the collection and analysis of language data. Here, then, we see how a set of changes in practice, driven by social considerations, can at least be partly supported by new technologies—in this case, technologies which facilitate work being done in distributed fashion.

Taken together, these two trends place increasing emphasis on the individual "pieces" of work involved in the creation of descriptive grammars, as opposed to treating them as a monolithic whole—the view encouraged by the traditional publication model. Moreover, independent of developments within work on language documentation itself, a more distributed approach to work forming the basis of descriptive grammars, in principle, has an additional potential advantage: It can facilitate more efficient use of research resources. An individual who is skilled at transcription may not be adept at morphological analysis, and a specialist in semantics may not be the ideal person to work on a language's phonemic system—and this is not to mention the problems that may arise when a linguist is asked to

[9] Of course, "intermediate" objects like this could be created without the aid of new digital technologies and some of them can be found in archives of field notes. However, before the rise of the internet, they were not typically made widely available or as carefully curated.

be not merely a grammarian but also an archivist, ethnographer, a lexicographer, or even a "linguistic social worker" (Newman (1998:14–17), see also Evans (2008:342–343)).

We arrive then, at a potential future where we move away from the publication-centered view of a descriptive grammar as a single-authored monograph to one where it consists of the compilation of set of "facts" about a language, each associated with a distinct provenance. This view of a "grammar" not only has clear connections to the current documentary paradigm, but it is also consonant with the reconceptualization of data embodied by the Semantic Web: Research results are "atomized" as it were, the barriers to registering a result (in the sense of developed in section 3.1) are significantly reduced, and the connections between discrete results can be made more explicit. Of course, it is a long road from the representation of a relatively simple observation like that seen in figure 2 to the construction of a graph representing a "complete" descriptive grammar. Nevertheless, we now have a core conceptual model of such a structure, technology that can implement that model, and even a field-internal motivation to use such a model. This means the creation of such an object is no longer simply something only to be imagined.

Within this broad vision, making the results of research public no longer needs to be delayed until it reaches the threshold of a "publishable unit" (see Broad (1981)) but can be done as soon as a useful observation is made, even if it constitutes something as simple as the discovery of a new minimal pair or a single unusual pattern of agreement. Of course, such "micro-discoveries" would not be associated with the same level of prestige as a curated publication.[10] What is important is that the Semantic Web, in principle, can allow them to be associated with the elements of publishing appropriate to them, e.g., registration, archiving, and reuse (see section 3.1), even if they fall short of the whole traditional publication "package".

There are clear potential advantages to reconceptualizing descriptive grammars as distributed, multi-authored resources. However, it is immediately apparent that valued features of the traditional descriptive grammar would be lost under such an approach unless additional measures are taken. In particular, the curatorial aspect of publishing (see section 3.1) imposes various important characteristics on the assembled "facts" which constitute descriptive grammars, two of which I will focus on here, *coverage* (section 4) and *coherence* (section 5). Of course, these are only parts of what constitutes a "good" grammar (see, e.g., Noonan (2006), Rice (2006b)), an issue which will be briefly returned to in section 6.2.

4 Coverage

4.1 Coextensivity and completeness An important aspect of good descriptive grammars is the extent to which their discussion (i) adequately addresses phenomena represented in the available documentation on a language and (ii) presents a reasonable overview of a

[10] The idea of publishing a "micro-discovery" can be clearly connected to the notion of micro-blogging, most prominently associated at present with the online service Twitter (http://twitter.com), which has been the subject of work considering how the content of micro-blogs can be made available not just on the World Wide Web but within the Semantic Web as well (Passant et al. 2010). See also Cysouw (2007:64) for relevant discussion on the notion of a "micro-publication" within work on language typology.

language's entire grammatical system.[11] I refer to these properties under the umbrella term *coverage* here, using the term *coextensivity* for the relationship between a description and available documentation and *completeness*, to refer to the extent to which a given description addresses those issues that are taken, at the time of publication, to be sufficiently central to basic linguistic theory (see Dryer (2006)) that they would be deemed necessary in a "complete" description of a language.

Completeness has seen more explicit attention than coextensivity, perhaps most famously in the form of Comrie & Smith's (1977) descriptive questionnaire. This can not only be used as a set of guidelines for ensuring that a grammar has covered a wide range of grammatical topics deemed descriptively significant (Noonan 2006:360) but has even formed the basis of full grammatical descriptions (such as Huttar & Huttar (1994)). An important aspect of completeness is that determining just what constitutes something like a "complete" description is within the purview of the general community of linguists rather than those working on a particular language.

The notion of coextensivity is instead connected to the actual documentation available in the production of a descriptive grammar (see also Mosel (this volume)). Therefore, a grammatical description of a language for which relatively little documentation exists may be considered to have satisfactory coextensivity even if its level of completeness is unambiguously inadequate. This would be the case, for instance, if the only material on a language that was available was a vocabulary list which might allow for the production of a phonological sketch, but little else. As such, it is important to distinguish between what is referred as coextensivity here and what one might call *documentary coverage*. This latter notion might be used to characterize the extent to which a documentary corpus actually includes the information needed to create a complete grammar of a language (see Berge (2010) for some discussion), regardless as to whether or not a descriptive grammar has actually been created on the basis of that record. A key distinction between coextensivity and completeness is that what constitutes completeness in a grammatical description can be laid out in general terms. Adequate coextensivity, by contrast, is dependent upon the particularities of the available documentation.

Coextensivity has seen not seem as much attention as completeness presumably because, before the development of the current documentary paradigm, it was difficult to evaluate due to the inaccessibility of the documentary materials on which descriptions were based. Even if a given descriptive grammar made clear, for instance, what percentage of available recordings or texts had been used in creating it, an inability to examine those texts would have made it essentially impossible for a reader to gauge the adequacy of its coextensivity. However, to the extent that the documentary bases of descriptions are expected to become more widely disseminated, explicit attention to adequacy in coextensivity would seem warranted. As pointed out by Evans & Dench (2006:25), new technologies are unlikely to result in significantly more analyzed materials than was previously possible. After all, the time it takes the linguist to conduct careful analysis will not change in proportion to the amount of material that can be made available. This means that it is likely to be the case, at least for the foreseeable future, that grammars will only be based on a sample of collected materials.

[11] By *available documentation*, I refer to the extent of the documentary resources (e.g., recordings, transcribed texts, lexical material, etc.) that those working on the description of a given language have access to when doing their work.

Therefore, the extent to which the studied sample may be representative of the language as a whole will be a significant concern.

An immediate problem with adopting a distributed approach to the production of electronic grammars is that the model in and of itself does not allow us to gauge the extent to which a given set of statements about a language's grammar is adequate with respect to coextensivity and completeness. Properly addressing such dimensions of coverage has normally been the responsibility of the single author of a traditional descriptive grammar. Dealing with them in a distributed context requires us to consider how we can augment Semantic Web (or similar) technologies with data processing and analysis methods more specific to the domain of language data. This is the topic of the next two sections, which, in turn, discuss possible digital approaches to completeness (section 4.2) and coextensivity (section 4.3).

4.2 **Modeling completeness** In understanding how to ensure adequate completeness in a descriptive grammar, it is first important to keep clear the fact that just what constitutes a "good" description in terms of completeness is not a technological problem but a scientific one, and it is driven by what is taken to constitute basic linguistic theory (Dryer 2006) at a given point in time. The key issue here is not, therefore, deciding what phenomena need to be included in a "complete" description, but, rather, how to digitally represent completeness in a way that facilitates creating grammars with a high degree of completeness and also allows us to automatically (or semi-automatically) evaluate the level of completeness attained by some digital descriptive grammar.

Of the problems to be discussed here, dealing with completeness is probably the easiest since there are already reasonable models to work from, in particular in work interested in typologically-oriented language comparison. Zaefferer (2006), for example, describes a system for creating a cross-linguistic reference grammar database which attempts to balance the need to ensure that each language is adequately described in its own terms against allowing comparable features across languages to be compared. In Semantic Web terms, this approach could be generalized first by formulating a pre-determined list of elements for cross-linguistic comparison expressed in the form of an accessible digital object. Then, the completeness of a digital descriptive grammar could be (at least partly) gauged by the extent to which each member of that list of elements is or is not associated with a specific RDF statement relating them to the other observations comprising a digital descriptive grammar.

Some work has suggested that the relevant elements of comparison should preferentially be drawn from the onomasiological domain rather than the semasiological one (Zaefferer 2006:122, Cristofaro 2006:140–142). However, it seems likely that a full consensus specification of completeness will need to include specification of of both functional and formal features. Comrie & Smith (1977:28), for example, contains a question regarding, in general terms, what kinds of morphological elements are used to encode the syntactic or semantic functions of nouns, regardless of the specific functions of those elements. Similarly categories like *head-marking* and *dependent-marking*, though having a functional component, primarily target formal variation, but have nevertheless been the subject of significant typological investigation (see, e.g., Nichols (1992)).

In any event, while an up-to-date specification of ideal completeness is lacking, this does not appear to be the result of particular technological impediments but, rather, a lack of

social effort. If there were sufficient interest, an initial proposal could probably be developed with relatively little work by examining and selectively merging the topics of a work like Comrie & Smith (1977) with more up-to-date surveys of specific typological phenomena, where available. In particular, the collected grammatical domains found in Dryer & Haspelmath (2011) would serve as a good recent "snapshot" of the typological state-of-the-art already available in electronic form (see also Levin et al. (2007:262–266)).[12]

The specific digital form of an object expressing the components of completeness could straightforwardly be based on the familiar notion of a questionnaire, where each question would be associated with a unique identifier. These questions would be "answered" via an RDF triple linking the topic of the question to supporting descriptive materials, where relevant via an intermediary node that would specify a categorial response to the issue raised by the question. The resulting series of "links" between questions and answers could then function very much like an index in a traditional descriptive grammar, though with the additional expressive power and utility afforded by digital technology (see also Zaefferer (2006:115) and Cristofaro (2006:162)). Though not dealing with the creation of full-fledged descriptive grammars, relevant work has been done in the domain of typological database construction. In particular, models have been proposed which seek to clearly separate the problem of isolating language-specific data illustrating the presence or absence of a feature from classifying a language (or construction) on the basis of that data into one of a fixed number of "types" (Bickel & Nichols 2002, Cysouw 2007).

Figure 5 augments figure 4 to schematize the integration of an element associated with completeness with the analysis of a particular language. The notion of *Basic clausal word order* is treated as an element that is part of completeness and is introduced into the overall descriptive graph of English by being associated with the earlier treatment of English as an SVO language.

Other elements of completeness could be associated with comparable nodes to what is seen in figure 5, though the relationships between the element of completeness and the descriptive analysis will, of course, not always be as simple. For instance, if a language showed split word order, this would require a more elaborate specification in the graph, just as it requires a more elaborate description in a traditional descriptive grammar. Similarly, if an element of completeness was associated with a phenomenon not attested in the language being described, conventions could be adopted to explicitly indicate its absence, comparable to what is found in the index of Haspelmath (1993) (see Good (2004:§2.1)). Furthermore, just as in a work like Comrie & Smith (1977), where grammatical questions are arranged in a hierarchy, a full scheme for completeness need not be composed simply of a "bag" of questions, but could be specified with additional structure and information—either using RDF or some other means.

Ultimately, the problem of understanding completeness can be understood as a kind of data modeling, and better completeness would amount to "filling out" more of the elements of an accepted model. For this particular aspect of descriptive grammars, consensus on the shape of the model itself—whether digitally encoded or not—appears to be the most difficult issue, with the technical problems being relatively attenuated.

[12] There is at least one instance of a widely disseminated language description tool, Fieldworks Language Explorer, which incorporates a kind of grammar model in its design that can facilitate achieving completeness (see Butler & van Volkinburg (2007), Rogers (2010) for reviews). See also Black & Black (this volume).

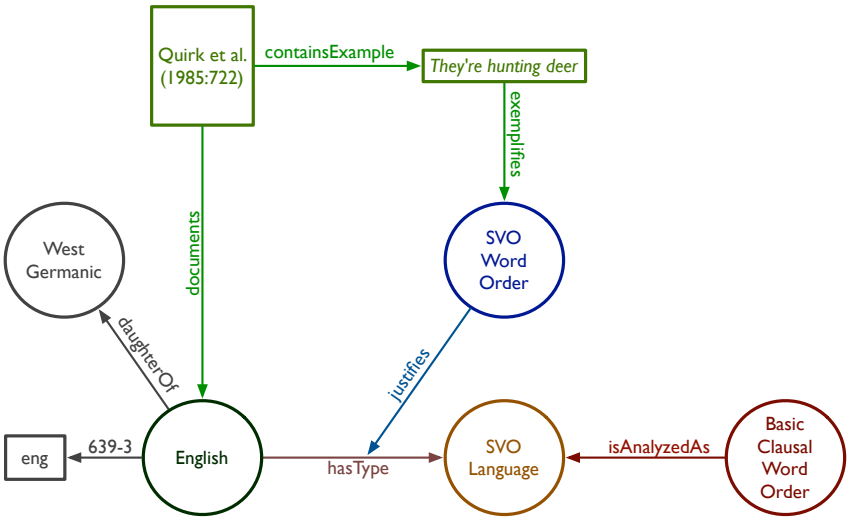

FIGURE 5.: Adding completeness to a graph-based description

4.3 MODELING COEXTENSIVITY Unlike completeness, which must clearly be connected to some community-wide consensus of what a description should include, coextensivity is particularized to the documentary record of a language. If the available documentary information is quite limited, then it might be expected that a description will be based (more or less) on all of the available data. However, for languages subject to even a moderate level of investigation, this will often simply not be possible. Rather, the general goal of the description is not that it be based on a detailed examination of all of the data. Instead, it should be based on a sample of the data that results in a description that is representative of all of the collected data.[13]

As mentioned above, there does not appear to have been significant work on how to measure adequacy of coextensivity. Nichols (2005), however, considers how much material is needed to produce adequate descriptions characterized in terms of numbers of words, clauses, and hours, and this would serve as a good starting point for work on this topic. Ultimately, these recommendations are probably best considered to be connected to adequacy in documentation rather than coverage. However, they might serve as proxies for coextensivity: For instance, her calculation that about 100,000 running words will allow for "basic documentation" suggests that a descriptive grammar based on a 100,000-word sampling of a much larger corpus is likely to be sufficient to allow for a reasonable level of analysis of the remaining part of the corpus by a future investigator, though there will probably still be significant gaps.

Bird (2010) (see also Reiman (2010)) describes a documentation model aimed at under-resourced languages involving the collection of oral texts, accompanied by oral annotation of a fraction of those texts, and a further written annotation for a fraction of the orally-annotated texts. While the clear intention of this process is to provide sufficient annotation

[13] As will be discussed in section 5, there are clear connections between coextensivity and aspects of coherence in descriptive grammars.

(in oral and written form) of a language to allow the unanalyzed portions to be analyzed in the future (Bird 2010:7), without further research, it seems impossible to know whether any description creatable on the basis of such a degree of annotated documentation would actually be sufficient for analyzing the entirety of the collected materials without the aid of a native speaker. In any event, the question of what kind of sample of documentary materials can be considered representative enough to form the basis of a description that would also cover the remaining materials appears to be an interesting one, and work in this area would be quite useful for developing general methods for assessing adequacy in coextensivity.

For transcribed documentary materials, there is at least the possibility of using a more direct means to assess coextensivity of a description. If a description can be expressed in a machine-readable form, automated methods could be employed to apply that description to the entire available dataset (see also section 5.2 for related discussion).[14] The coextensivity of the machine-readable description could then be considered to be adequate if it can provide appropriate parses for unanalyzed material. Of course, while some analytical domains, such as morphological parsing, have seen significant work in terms of relating traditional documentation to machine-readable parsers (see, e.g., Black & Simons (2008)), most domains of grammar are not yet well covered. Moreover, while there is at least some relevant work in the domain of syntax (see section 5.2), there seems to be little to no work along these lines in the domain of phonology (e.g., allowing a user to define a phoneme inventory and phonotactic constraints and checking to see if transcriptions are consistent with them).[15]

While completeness appears to be representable via data modeling, as discussed in section 4.2, this solution does not appear to be applicable to coextensivity. In particular, the fact that coextensivity is defined in terms of whatever documentation happens to be available means that it is not amenable to a treatment involving any kind of general data model. Rather, a more appropriate approach for modeling coextensivity would appear to be one based on notions from natural language processing involving the extent to which a parser that has been "trained" on a subset of available data can assign correct analyses to data it has not been trained on (see Resnik & Lin (2010) for overview discussion).[16] Implementing this kind of approach generally for digital descriptive grammars is likely to be quite difficult, however. Creating the relevant kinds of computational systems, even for well-described languages, is, at this point, still quite time-consuming and requires resources well-beyond those usually available to those engaged in language description. Moreover, existing methods are often heavily reliant on the availability of large quantities of textual materials, which are simply unavailable for most languages (see also Bird (2011)).

5 Coherence

[14] In principle, these methods could be applied to untranscribed materials as well if they could somehow be associated with a reasonable, automatically-derived transcription using techniques from work on speech recognition. But, of course, that adds a significant, additional element of complexity.

[15] There are, however, tools that allow one to discover things like phonotactic constraints on the basis of existing transcriptions, for example Phonology Assistant (see Dingemanse (2008) for a review). Furthermore, the work described in Moran (2012), though oriented towards typological investigation rather than description of individual languages, is clearly relevant here.

[16] Abney & Bird (2010), Bird (2011) offer parallel proposals in suggesting that one metric for determining whether available documentation is adequate for capturing the properties of a language is that it is sufficient for training a machine translation system.

5.1 THE COMPONENTS OF COHERENCE A second clear problem with the possibility of taking a distributed approach to the development of descriptive grammars is that, without specific attention, they run the risk of becoming incoherent due to distinct conventions and analyses adopted by different researchers working on pieces of the documentation or description. Maintaining coherence is, of course, a problem for all kinds of research, and my goal here will not be to develop the notion generally, but, rather, to try to specifically model the components of coherence in descriptive grammars. While the components to be discussed may not exhaust all of what is required for coherence in descriptive grammars, those given below appear to represent at least four prominent ones.

1. **Consistency in terminology for language-specific categories**: The use of terms for language-specific categories is ideally consistently applied throughout.
2. **Clarity in terminology for the general audience:** The relationships between language-specific categories and comparative concepts (in the sense of Haspelmath 2010) are ideally made explicit.
3. **Consonance of analyses with documentation:** The descriptive analyses should ideally be in agreement with what is found in the entire documentary record.
4. **Compatibility of analyses with each other:** The analyses of specific grammatical patterns are ideally compatible with each other throughout the description.

As indicated, the components above represent ideals, and even single-authored grammars will fail to adhere to them fully. Nevertheless, they suggest points to pay special attention to if grammatical analysis is to be distributed since coherence is likely to be an especially problematic area in this regard.

There are clear connections between certain aspects of coverage and certain aspects of coherence, at least when these two concepts are understood informally. This is most clearly seen in relation to coextensivity (see section 4.1) and the components of coherence termed *consonance* and *compatibility* above. Whether or not the coextensivity of a description would be considered adequate clearly hinges on the extent to which it is consonant with the documentation and the extent to which all of its analyses can be brought together into a non-contradictory whole. At the same time, it seems reasonable to separate these notions. Coextensivity is intended to reflect the link between available documentation and what level of description is possible given that documentation, while the components of coherence are more general than this. Nevertheless, practically speaking, an important consequence of the connection between coextensivity and those two components of coherence is that they may require overlapping technological support.

In the next section, I will discuss how the components of coherence mentioned above could be modeled digitally and discuss existing technologies that would be relevant for the implementation of those models, thereby complementing the discussion in section 4 and suggesting additional ways in which the Semantic Web vision might be augmented to facilitate the creation of digital descriptive grammars in a distributed fashion. Many of the points to be discussed below should resonate even for those working on traditional grammatical monographs, but, again, the idea that the work might be done by many individuals, rather than just one, brings the relevant issues to the fore. Under such an approach, it will

no longer be obvious who is in charge of the "quality control" needed to achieve coherence, which necessarily prompts us to consider how we might develop means of ensuring that it is maintained that do not depend on the presence of a central "author".

5.2 Modeling coherence

Consistency In discussing *consistency* for the terminology used in a grammatical description, I refer only to consistency for the terms used to describe the categories found in the language in question. This dimension of coherence, therefore, is not intended to apply to the use of terms for general linguistic concepts, of the sort contained within the GOLD ontology, which I treat as relevant, instead, to the notion of *clarity*. The distinction between language-specific categories and general linguistic ones is not always well-maintained within descriptive grammars, though it is found, for instance, in Haspelmath (1993:11) (on the basis of a practice employed in Comrie (1976:13)). In that grammar, capitalized terms are used for language-specific categories and lower-case terms for general linguistic notions (see Good (2004:§2.1)).

Ultimately, the issue of maintaining consistency in a description can, in large part, be understood as a problem of terminology management (or *terminography*), which is a distinctive area of research in its own right (see, e.g., Wright & Budin (1997:1–3) and Cabré (1999:115–159)). Terminology management has some overlap with lexicography. However, it is primarily oriented with relating concepts to forms, rather than forms to concepts, as is typical of lexicography (Cabré 1999:7–8) (thus making it more comparable to the onomasiological rather than the semasiological approach to descriptive grammars).

Descriptive linguistics generally already involves a fair amount of informal terminology management (as evidenced, for instance, by ubiquitous glossing abbreviation lists and efforts like Bickel et al. (2008)). Therefore, even if we did not adopt a distributed approach to the writing of descriptive grammars, the field could clearly benefit from more robust (and ideally partially automated) techniques for managing the terms used to describe a given language. Furthermore, once one considers the possibilities for more distributed authorship, such techniques would seem to become a necessity in order to facilitate harmonization of terms across content contributors, whether these are in Semantic Web form from the start or partial Semantic Web annotation is attempted for legacy resources. Work of the latter sort could specifically build on existing research in the area of (semi-)automated term extraction (see Ahmad & Rogers (2001)).

On the whole, technological support for the consistent use of terminology within a grammatical description appears to be largely underdeveloped. However, it seems like a potentially profitable area in which to focus efforts in the near term. This is due to the possibility to make use of existing work on terminology management in general, as well as on terminological support for the component of descriptive coherence termed *clarity* here. This latter area of research will be discussed in the next section, and it can likely serve as a useful model for the development of tools facilitating consistency in the use of language-specific terminology, as will be briefly discussed below.

Clarity A well-known problem of linguistic description is the use of the same word to refer to different grammatical concepts or the use of different words to refer to the same

concept across descriptions (see, e.g., Cysouw et al. (2005:§1) and Zaefferer (2006:114)). In either case the potential for confusion is clear, and the issues are especially acute for work attempting to automate, or partly automate, language comparison on the basis of digital materials.

This has been one of the key motivations behind the development of the GOLD ontology (Farrar & Langendoen 2003, Farrar & Lewis 2007, Farrar & Langendoen 2009), already discussed in section 2, which represents the longest-running effort for the exploitation of Semantic Web technologies for use in descriptive linguistics. GOLD provides a set of standardized concepts relevant to grammatical description that can be used to formally define a term used in a language description in general linguistic terms. For instance, it would allow for the specification that the English Past Tense verb form expresses a meaning that can be reasonably related to the general notion of *past tense* specified in GOLD. Of course, in this case, the terminology is not particularly problematic. However, when dealing with a form like the Latin Perfect, which would be generally characterizable as a combination of *perfective* and *past*, rather than a *perfect* (Comrie 1976:13), being able to relate a language-specific term to more general categories with readily-accessible definitions, as GOLD allows for, is clearly valuable.

GOLD both provides a standardized termset (with associated URIs for each term) and structures the members of the termset into an ontology (consisting of a taxonomy plus some additional information) in order to facilitate automated processing of linguistic data. Such an ontology is not a strict requirement to achieve clarity in use of terminology, and a somewhat simpler model is provided by ISOcat (Kemps-Snijders et al. 2008a,b).[17] ISOcat provides an open registry for data categories relevant to linguistic resources, allowing an individual linguist or groups of linguists to publicly register the terms they use and associate them with basic descriptions of the meaning of the terms. It also provides a unique identifier for each term which can be used in a Semantic Web context.[18]

ISOcat has a somewhat more "open" model than GOLD, insofar as it allows different groups to register their own categories. By contrast, the addition of new categories to GOLD is more centrally managed. At the same time, GOLD's community model explicitly allows for different subcommunities of linguists to extend the ontology to suit their specific needs (see Farrar & Lewis (2007:53–55)). Taken together, an open registration system like ISOcat in conjunction with tools making it straightforward to associate an ISOcat category with the appropriate GOLD concepts could provide a significant degree of support for some of the issues relating to consistency in the use of terminology discussed above.

There does not yet appear to be significant use of resources like GOLD or ISOcat to enhance traditional descriptive work. However, due to the efforts that have been expended on their development, terminological clarity can probably be considered, at present, the best supported component of coherence discussed here.

Consonance The development of the documentary paradigm has altered expectations regarding the extent to which the data on which a description is based should be accessible.

[17] http://www.isocat.org/

[18] While ISOcat's structure does not allow for the specification of an ontology for its categories, there has been work attempting to develop a degree of ontological structure around the ISOcat categories in a parallel resource (Wright et al. 2010, Windhouwer & Wright 2012).

This brings to the fore an issue with respect to coherence which was always present but was often of little practical significance: To what extent is a given description, which will often be based on a detailed examination of only a subset of documentary materials, in agreement with the entire body of available documentation for a language? Section 4.3 discussed related issues from the point of view of ensuring adequate coextensivity.

Because the documentary expectations that have made this problem a practical concern are relatively new, this issue does not appear to have received significant attention. The focus, up to the present, has instead been on developing methods through which a given descriptive claim can be verified on the basis of supporting documentation in a relatively richly annotated corpus (see, e.g., Thieberger (2009)). But, in the long run, it would also be ideal if it were possible for sparsely annotated documentation to be automatically processed on the basis of existing connections between documentation and description in order to locate possible cases of discord between the documentation and the description. This processing could involve such things as, for example, the detection of phonological processes that fail to apply as expected, the discovery of members of a morphological paradigm which have not been accounted for, or flagging uses of a discourse marker that do not match its description.

These are, of course, difficult tasks to the extent that they require the development of sophisticated parsers based on machine-readable grammars—the descriptive grammatical equivalent of debugging software (see also section 4.3). One potentially promising relevant line of work in this regard involves automated processing techniques that make use of manual annotation of a fragment of a corpus combined with *active learning* in which the user provides feedback to an automated system to help improve its performance. This has been applied to the domain of interlinear glossed text (Baldridge & Palmer 2009, Palmer et al. 2009, Palmer 2009, Palmer et al. 2010) and could, in principle, be applied to other domains as well, reducing the effort required to create useful parsing tools for a given language. However, the path from experimenting with these methods to providing robust tools for checking the complicated relationships involved in consonance between documentary products (e.g., transcribed texts) and descriptive ones (e.g., a complete grammar based on those texts) is likely to be a relatively long one. (A different line of research involving machine-readable grammars, more relevant to the notion of compatibility, but with potential applications to consonance as well, will be discussed below.)

An open question in research along these lines is where the most effective "balancing point" might be for manual versus automatic annotation and whether or not even relatively simple types of annotation might facilitate the use of automated methods in ways that make more effective use of an expert's time. For instance, it will often be the case that documentary recordings will contain stretches of different languages, most typically a language of wider communication and a language being documented. Annotating which stretch is in which language may be able to be done by someone without special linguistic expertise on a subset of the recordings to train a machine to do the work across the whole documentary corpus. This would give an expert linguist a head-start on more complex kinds of annotation by making it easier for them to locate the most important stretches of recorded data. The maintenance of consonance in the relationship between documentary products and derivative descriptive ones would, thereby, be facilitated. Such a scenario suggests the possibility that taking full advantage of a more distributed approach to grammatical description may

require us to consider crafting non-prototypical documentary products—in this case a very sparse kind of linguistic annotation.[19]

Compatibility The final dimension of coherence to be discussed here, compatibility, has already seen some attention in the computational linguistics literature in the area of grammar engineering, which seeks to create machine-readable versions of formal grammars (see, e.g., Bender (2008b)). Among other things, these grammars allow linguists to automatically test the extent to which their analysis of a given phenomenon interacts with other analyses as expected, something which is more or less impossible to do by hand.[20] Moreover, there have been efforts to ensure that grammar engineering work done for better-resourced languages can be used to facilitate the development of machine-readable grammars for lesser-resourced languages (Bender et al. 2010), addressing an issue raised at the end of section 4.3 in the discussion of coextensivity. Such tools can even potentially play a role in helping linguists choose among competing descriptive hypotheses (Bender 2010).

Bender (2008a) reports the results of work which made use of a general grammar engineering system to create a machine-readable grammar for a language typologically quite distinct from those languages that have informed most computational research. Strikingly, it was possible to create a reasonable new machine-readable grammar for this language in a timeframe of about six weeks. This is, of course, only a small fraction of the time it takes to write a traditional descriptive grammar. It suggests that work in grammar engineering has reached a point where relatively limited collaborations between linguists specializing in this area and those working on underdescribed languages may yield worthwhile results for language description with respect to ensuring compatibility among analyses. More generally, this work provides a model for how to move forward in the development of computational techniques to facilitate the creation of digital descriptive grammars: Lessons learned from the development of computational tools for better-resourced languages, often at great cost, can ultimately be applied to lesser-resourced languages at much lower cost (see also Bender et al. (this volume)).

The work described above is primarily focused on syntactic phenomena. Comparable tools exist for some aspects of morphophonological analysis (see, e.g., Black & Simons (2008) and Maxwell (this volume)), though there has not yet been much work on integrating tools from each of these domains (though see Bender & Good (2008) for some discussion of possibilities). Furthermore, other domains of grammar do not appear to be well-supported yet at all, with phonology standing out as an area where the lack of obvious tools does not seem to present major technical problems but, rather, results from a lack of dedicated effort (though see Moran (2012)). For example, a tool allowing a linguist to specify phonotactic constraints and ensure their overall compatibility would appear to be much more straightforward to develop than the already existing tools supporting syntactic analysis mentioned above. Nevertheless, to the best of my knowledge no such tool exists. (See also section

[19] This scenario also recalls recent work, such as Snow et al. (2008), which suggests that internet marketplaces where workers can be recruited to perform relatively simple annotation tasks at much lower rates than individuals with linguistic training may be useful for language research. However, see Fort et al. (2011) for discussion of ethical complications potentially associated with using such marketplaces, related to the limited rights and wages typically granted to workers.

[20] Grammar engineering can also play a role in maintaining consonance, insofar as it can help locate instances of data that cannot be analyzed at all by a given formal grammar, suggesting gaps in a description.

4.3.) In other domains, like semantics and pragmatics, the tool gap is less surprising given the difficulties of conducting even informal descriptive work in these areas.

While the discussion here has been primarily in terms of issues regarding parsing language data, some computational systems are designed to be bidirectional, both parsing and generating language data (see Bender & Langendoen (2010:6) for discussion relevant in the present context). While I am not aware of specific proposals in this regard, the ability of such systems to generate data has potential applications for testing compatibility (as well as consonance) of grammatical analyses adopting onomasiological approaches. This would require a machine-readable means to describe the relevant "functions" which would serve as an input for the generation of predicted forms in a given language. The generated forms could be compared against attested forms to gauge the extent to which they match each other.

6 Conclusion

6.1 Building on existing infrastructure Overall, we have seen above that, if we take the distributed model of research implied by Semantic Web technologies seriously, we are presented with the problem of losing desirable characteristics of traditional resources not embedded within the design of the Semantic Web itself. However, with appropriate conceptual models of key components of a traditional resource, we can devise explicit characterizations of what we have lost which allow us to see how we can augment the Semantic Web (or any comparable endeavor) in ways that reincorporate the "missing" features into our new kinds of resources.

In focusing on coverage and coherence, the overall vision that emanates from this discussion is one where Semantic Web technologies would form a basic infrastructure to express statements in ways that make them straightforwardly registrable and reusable, but where the set of statements comprising a grammatical description would be subject to additional data processing and validation. This would involve techniques ranging from the development of formal data models (to help verify completeness), to the deployment of tools for terminology management (to help ensure consistency), to the use of machine-readable formal grammars (to help test for compatibility).

At the same time, significant areas have been identified where tool support or appropriate models of practice are lacking, though a path to developing those tools or models can be outlined. This was seen, for instance, in the domain of coextensivity, where there has been relatively little research on determining what an appropriate documentary "sample" might look like. It was also seen in the domain of consonance where tools for verifying that nowhere in the documentation is a description contradicted have not received serious attention on either the conceptual or implementation side. In both cases, methods from natural language processing were put forth as presenting possible solutions to these problems.

Nevertheless, a significant result, I believe, of this survey is the extent to which many existing technologies provide models (if not necessarily "off-the-shelf" tools) for how we might go about developing a tool "ecology" (see Good (2007)) for distributed grammatical description with less effort than might appear to be needed at first. Importantly, even if a given tool type requires re-implementation to be usable in a documentary and descriptive

context, modeling a new tool on an existing one is likely to save considerable time and resources, when set against developing it completely anew.

6.2 **DECONSTRUCTING *our* PROBLEMS** To conclude, this has paper has been intended to be an exercise in what one might call "theoretical" electronic grammaticography (though grounding the discussion in specific relevant technologies). While its starting point (see section 2) was a technical discussion of the Semantic Web, ultimately its specific technical details were of less importance than the model that it provided for a more distributed approach to data dissemination and curation, which has clear potential applications for many areas of scholarship, but especially descriptive grammars. This is due to their complexity in terms of the relationship of descriptive claims to documentation, the breadth of their subject matter, and the interconnectedness of the elements of description.

While the discussion here has been framed as one where the distribution of the work of describing a language is dispersed across multiple contributors, the long-term nature of most descriptive work also means that it is distributed across time, even if there is only a single main creator. Because of this, many of the models and techniques described here would certainly also be of value in cases where effort is expended primarily by one person, but over a long enough period that they may find it difficult to keep track of their own progress.

Two particular issues were the focus here, coverage and coherence. These are undoubtedly important aspects of traditional descriptive grammars. However, it should be emphasized that they are far from the whole story. For instance, one of the criteria listed by Rice (2006b:396) as an aspect to writing an effective grammar is "richness of illustration", a clearly important concern not considered here at all.

Moreover, the framework introduced here does not allow for the expression, in any straightforward way, of the idea that languages have a basic "plan" or structural "genius", to borrow from the famous formulation of (Sapir 1921:127). This idea has been reflected in the intuitions of both formal and descriptive linguists (see, e.g., Baker (1996:6–9) and Evans & Dench (2006:3–4)). However, it is difficult to imagine how it could be expressed in the deliberately reductionist framework of the Semantic Web, making it clear that we should not understand a reconceptualization process like the one offered here as a means of replacing our traditional understanding of what makes a descriptive grammar "good". Rather, it should be seen as an exercise in understanding how we can use technology to enhance what we already know to be good (see also Dobrin et al. (2009:42–43)).

Ultimately, the goal of a study like this one is not to set our agenda on the basis of what a given technology offers but, rather, to clarify which existing technologies can fulfill our needs and to map out plans for the creation of new technologies. The Semantic Web may have prompted consideration of many of the ideas discussed here, but it cannot serve as a substitute for crafting a vision for the future of linguistic resources with our own values serving as its foundation.

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The grammatical description as a collection of form-meaning-pairs

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This paper analyzes the structure of books containing grammatical descriptions and builds up on work by Good (2004). It argues that the discussion of morphology, syntax, semantics, and intonation found in grammatical descriptions can be seen as a collection of interdependent form-meaning-pairs. These form-meaning-pairs form part of the larger structure of frontmatter, mainmatter and backmatter (Mosel 2006) and have themselves an internal structure which includes, among other things, linguistic examples as formalized by Bow et al. (2003).

1 Introduction In this paper I will be concerned with the structure of a certain genre of texts, namely grammatical descriptions.[1] These texts have as an aim to store knowledge about the grammatical structure of a language, which may have a long literary tradition like French, or about which little may be known, as for Vedda, a small language in Sri Lanka. One thing which is important in the context of this paper is that I am dealing with *texts* and not with abstract entities like computational grammars which generate sentences (Maxwell this volume). Neither do I deal with the mental representations of grammatical knowledge. While I acknowledge the relevance of the latter two concepts, which form an interesting topic for formalization in themselves, in this paper I will concentrate on texts which are used to communicate grammatical information about a language from a knowledgeable person (the describer) to a person wishing to know more about the language (the reader). This is to say, I treat the "grammatical description as a communicative act" (Payne 2006).

2 Content-based and form-based structures In an ideal world, all grammatical descriptions would conform to the same schema. Once this schema is established and applied to all grammars, the reader will be able to navigate a new description very easily. An approach pursuing the unification of the description of grammatical knowledge is for example the Crosslinguistic Reference Grammar project (Peterson 2002, Zaefferer 2006, Black & Black this volume). This approach presents a more or less elaborate apparatus for filling in grammatical information in predefined fields. The value of these approaches is heavily dependent

[1] I would like to thank Jeff Good, Nick Thieberger, and Michael Cysouw for comments on earlier versions of this paper.

on the quality of the underlying apparatus. In case the language in question does not exhibit a required phenomenon,[2] or it shows phenomena which were not known at the time when the apparatus was designed, the description cannot be implemented. Keeping track with theoretical developments (Upward-compatibility) seems to be a reasonable expectation for a formalization of grammatical description,[3] but it is unclear how this can be done with a rigid formalization of 'what grammar is like' at the foundation of the apparatus. Furthermore, an apparatus based on the predefined categories necessarily relies on the cross-linguistic applicability of these categories, but it is still subject to debate whether it is even possible to formulate crosslinguistically valid categories at all (Haspelmath 2007). Moreover, language describers who do field work in remote places often have a strong personality with a disliking for being told how to describe 'their' language. The feeling that 'their' language is unique and cannot be pressed into a one-size-fits-all approach is widespread (Weber 2006). Even without the fundamental problems alluded to above, it is unclear whether a 'universal schema' is actually in line with the wishes of the describers. Finally, a universal schema is difficult to retrofit on already existing descriptions, which might be desirable if one wants to broaden the domain of semantic searches.

The 'universalist' or content-based schemas mentioned above have as an implicit aim to structure what grammar is like, with 'grammar' being used in its sense of 'mental representation'. Following Good (2004) and Nordhoff (2008), I take a slightly different approach in structuring what *grammatical descriptions* are like. This approach can be called 'form-based'. In the content-based approach, the elements of the structure are phonemes, words, suffixes etc, while the form-based approach has paragraphs, examples, and glosses as its elements. No claim is made about the universal applicability of the grammatical terms in the descriptions. Every author can describe the language how they see fit. However, the hypothesis is that grammar authors will make use of a number of typical textual elements like 'linguistic examples', 'paradigm tables', 'word-gloss-pairs' etc (Good 2004). Good (2004) surveys a sample of grammars and lists recurring structural elements, which are nested in a certain way. The highest structural element he recognizes is the 'annotation', which can contain 'exemplars', 'prose', 'references' and 'links to ontologies', and further annotations in a recursive fashion. He formalizes this nested structure in a DTD. The linguistic example itself is at a lower level in the structure. Theoretical discussions of its structure can be found in Drude (2002), formalizations are given in Peterson (2002) or Bow et al. (2003). In this paper, I want to concentrate on the higher elements in the structure, i.e. chapters and sections, while also refining Good's analysis of the 'annotation'. I use lower level elements occasionally where necessary, but often omit them to keep the presentation visually appealing and free of clutter. My basic approach has as an aim to be compatible with Bow et al. (2003) on the low level and Good (2004) on the mid-level.

3 The sample I will exemplify my claims in this paper by a sample of descriptive grammars which includes all traditions and publication forms and covers different areas of the globe. The sample consists of

[2] For a non-technical overview of how little we can assume about language structure, see Evans & Levinson (2009).

[3] See Mosel (2006) for the necessity to update theoretical analyses.

- Bloomfield (1962), a grammar of the North American language Menomini
- Seiler (1985), a grammar of the North American language Cahuilla *
- Li & Thompson (1981), a grammar of Mandarin Chinese
- Epps (2008), a grammar of the Amazonian language Hup
- Buechel (1939), a grammar of the North American language Lakota *
- Haspelmath (1993), a grammar of the Caucasian language Lezgian *
- Frohnmeyer (1889), a grammar of the Indian language Malayalam
- Newman (2000), a grammar of the Subsaharan language Hausa *

While all books were consulted, a general discussion will take up too much space, which is why the general findings are discussed based only on the starred items in the list above. In the remainder of this paper, I will follow Good (2004) in claiming that grammatical descriptions are semi-structured texts. When they are annotated for structure, semantic searches become possible, which is a useful resource for typologists. Figure 1 from Haspelmath (1993) illustrates a typical layout of a descriptive grammar.

In Figure 1, the discussion is made up of prose, which is found before and after examples in a particular format which are use to illustrate the topic at hand, distributive numerals in this case. As a first step in structuring the text, we can separate the examples from the prose which discusses them (cf. Good 2004). The internal structure of the examples can then be worked out, as done for instance in Bow et al. (2003). The prose part has received less attention overall, which is why I will focus on this aspect here, next to the whole overarching structure of the book.

4 The structure of grammatical descriptions: an overview Taking a look at the table of contents of the books in the sample, we find a certain recurrent ordering in the topics discussed. I take these findings to be uncontroversial, so I give an abbreviated XML-notation right away.[4]

(1)
```
<book>
  <frontmatter>
    <tableofcontents/ >
    <listoftables/ >
    <listoffigures/ >
    <listofabbreviations/ >
    <acknowledgments> ...  </acknowledgments>
  </frontmatter>
  <mainmatter>
    <background> ... </background>
    <phonology> ... </phonology>
    <morphology> ... </morphology>
```

[4] The actual ordering of the chapters in the mainmatter may differ (Mosel 2006), but what it is important here is that they are discussed as part of the mainmatter; the actual internal ordering is less relevant, as will be discussed below.

13.1.7. Distributive numerals

Distributive numerals are formed by reduplication. The stress is on the first instance of the numeral. prose

(599) *sá-sa(d)* 'one each'
q'wé-q'we(d) 'two each'
púd-pud 'three each'
c'uwad-c'uwad 'fifteen each', etc. examples

In complex numerals, only the last component is reduplicated (Gajdarov 1987:63). prose

(600) *wiš-ni q̆an-ni wad-wad* '125 each'
q'ud wiš-ni c'urugud-c'urugud '416 each' examples

If the last component is *wiš* '100', *ağzur* '1000', or *million/milliard*, the component that precedes it is reduplicated. prose

(601) *ağzur-ni q'ud-q'ud wiš* '1400 each'
q̆an-ni irid-irid million '27 000 000 each' examples

Examples for the use of distributive numerals: prose

(602) a. *Ča-z q'we=q'we ič ťa-na.* (G54:155) examples
we-DAT two=two apple become-AOR
'We received two apples each.'

b. *Fejzillah sa=sa xtrünwi.di-n wil-er.i-z kilig-na.* (HQ89:8)
Fejzillah one=one villager-GEN eye-PL-DAT look-AOR
'Fejzillah looked into the eyes of the villagers, one (villager) at a time.'

c. *Emirmet.a muhman-ar acuq'ar-na. Axpa sa=sada-waj*
Emirmet(ERG) guest-PL make sit-AOR then one=one-ADEL
žuzun-ar awu-na. (Q81:112)
question-PL do-AOR
'Emirmet made the guests sit down. Then he asked them questions, one (guest) at a time.'

FIGURE 1.: The discussion of the distributive numerals in Haspelmath (1993)

```
    <syntax> ... </syntax>
    <semantics> ... </semantics>
  </mainmatter>
  <backmatter>
   <references/>
   <wordlist/>
   <texts>
    <text id="story1"> ... </text>
    <text id="recipe3"> ... </text>
   </texts>
  </backmatter>
 </book>
```

The nature, relevance and functions of front- and backmatter are similar to what we find in other kinds of scientific books (Mosel 2006) so that the need to discuss these parts in this paper is less urgent. I will focus on the parts of the mainmatter then.

5 The structure of the mainnmatter

5.1 Background Grammatical descriptions typically contain a chapter on the sociohistorical background of the language (Lehmann 2002). In that chapter, the history and current sociological and political situation of the speech community is discussed. Topics covered are genealogical affiliation, geographical and political distribution, demographic factors such as ethnicity, religion, occupation and institutional representation. This part of the mainmatter does not seem to exhibit particular strong recurring structure and it does not seem wise to impose too tight a skeleton on it, so that I will treat it as unstructured data here.

5.2 Morphosyntax: form-meaning-pairs ordered according to form Departing from the order normally found of books, I will now first discuss morphosyntax before coming back to phonology – which is normally the first thing to be discussed – in a minute. Depending on the language at hand, the division between morphology and syntax can be clear or rather subtle. While in Latin, the distinction is easy in most cases, other languages, like Tamil for instance, present challenges to the analyzer when they have to decide whether a given item is a suffix, an enclitic or an independent particle. There are ongoing theoretical discussions in particular languages about whether there is a division between morphology and syntax, and where it would be located (See Culicover & Jackendoff (2005) for an overview for the English facts, Lehmann (2002) for the consequences for language description). In light of these facts, it does not seem wise to impose a division in the schema until the differences are sorted out. What morphological and syntactical analyses have in common is that there is a certain form X which is said to have a certain function F. Whether X is treated as belonging to the morphological domain or to the syntactic domain is not substantial here. As an example, we can take the English possessive marker *'s*. No matter the analysis, we can say that *'s* is used to encode possession, widely construed. This is to say we are dealing with a *form-meaning-pair*. The form *'s* of the English language is paired with the meaning *possession*. In this paper, I propose that most of the morphosyntax of

a language can be treated as discussion of form-meaning-pairs (henceforth abbreviated as 'fomp').[5] Form-meaning-pairs consist of a topic of the discussion, which is at the same time the lemma (the name if you want) of the discussion. This topic is discussed with the help of illustrative examples[6] and surrounding prose.[7] We can illustrate this with the following fragment:

(2)
```
<fomp type="form-to-function" lemma="'s">
  <prose>
    The phrasal affix <form> 's" </form>  is used to
    code <meaning> possession </meaning>.
  </prose>
  <examples>
    <example> My friend's car </example>
  </examples>
   <prose>
     As we see in the example above, the affix
     attaches to the right edge of an NP, in this
     case <objectlanguage> My friend </objectlanguage>.
   </prose>
</fomp>
```

As a consequence of the bipartite nature of the form-meaning-pair, discussion of the sign can focus on the form part (signifiant) or on the meaning part (signifié) (Lehmann 2004b). Figure 2 from Seiler (1985) shows a neat separation between the discussion of formal properties and the discussion of functional uses. In the formal part on top, marked in red, allomorphs, a purely formal phenomenon, are discussed, while in the functional part on the bottom, marked in blue, the communicative situations where this morpheme can be used are explicated, in this case WISHES.

The division in a discussion of formal properties and functional properties can be squared with the alternation between prose and examples. Figure 3 shows such a more complex configuration.

This structure of the text can be represented in semantic markup (3).

(3)
```
<fomp>
  <formaldescription>
```

[5] A 'fomp' is a subset of the 'Annotation' element proposed by Good (2004). 'Annotations' are broader and could be used for other domains as well. It is a topic for further research to determine the relations between the general superordinate 'annotation' type and the subset of form-meaning-pairs on the one hand and other types of description used in grammars (e.g. phonology) on the other hand.

[6] It seems sensible to have a container to contain a collection of individual examples illustrating aspects of the same phenomenon each. Good (2004) calls this container `<exSet>`. In line with the general use of full words in markup in this paper, I use `<examples>`, but the two terms can be subsituted for each other.

[7] The prose has an internal structure as well, consisting of running text interspersed with some special elements like references, *word* 'gloss'-pairs, technical terms and references. Specialized markup for these elements and links to ontologies enhance the computational usability of the grammatical description (Farrar & Langedoen 2003, Good 2004). For reasons of space and in order not to clutter the examples with tags, I omit the markup around the mentioned elements.

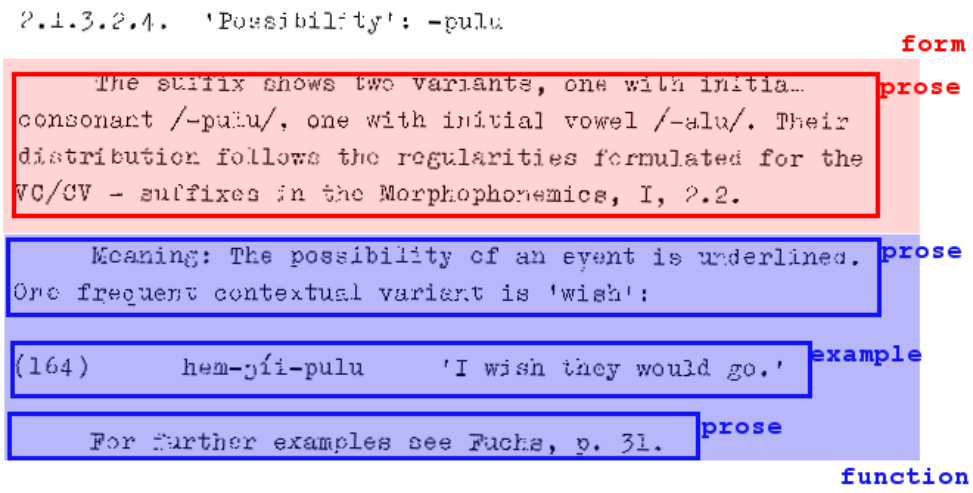
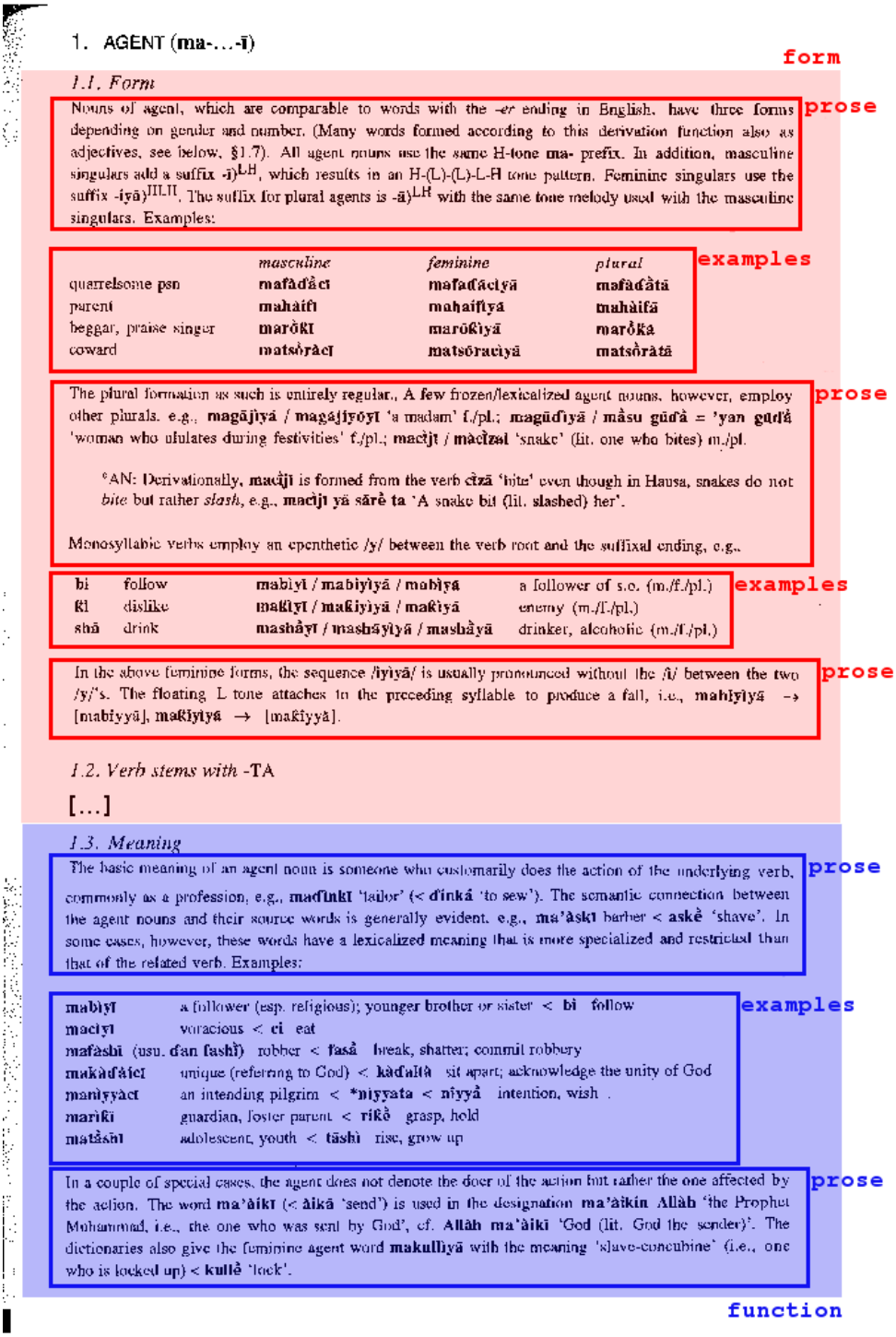


FIGURE 2.: The discussion of the morpheme *pulu-* in Seiler (1985)

```
      <prose>
        <form> XYX </form> has the following properties
      </prose>
      <examples>
        <example> ...</example>
      </examples>
    </formaldescription
    <functionaldescription>
      <prose>
        <form> XYX </form> is used for <meaning> Function
        FGH </meaning>
      </prose>
      <examples>
        <example> ...</example>
      </examples>
    </functionaldescription>
  </fomp>
```

The kind of discussions we find in morphology have similarities to what we find in lexicography (Schultze-Berndt 1998, Mosel 2006, Weber 2006). First the forms are enumerated, then the possible meanings are given; additional information about domain, register or etymology may also be provided. In light of the similarity to the lexicon, I will follow a suggestion by Lehmann (2004) and call the space where these things are discussed *Morphemicon*.

5.3 COLLECTIONS OF FOMPS In grammtical descriptions, as in other books, related phenomena are often grouped together. Sentences which cover related ideas are grouped into a



1. AGENT (**ma-…-ī**)

form

1.1. Form

prose

Nouns of agent, which are comparable to words with the *-er* ending in English, have three forms depending on gender and number. (Many words formed according to this derivation function also as adjectives, see below, §1.7). All agent nouns use the same H-tone **ma-** prefix. In addition, masculine singulars add a suffix **-ī**)^{LH}, which results in an H-(L)-(L)-L-H tone pattern. Feminine singulars use the suffix **-iyā**)^{HLH}. The suffix for plural agents is **-ā**)^{LH} with the same tone melody used with the masculine singulars. Examples:

examples

	masculine	*feminine*	*plural*
quarrelsome psn	**mafàdâcī**	**mafadâciyā**	**mafàdâtā**
parent	**mahàifī**	**mahaifiyā**	**mahàifā**
beggar, praise singer	**marôkī**	**marôkiyā**	**marôkā**
coward	**matsôràcī**	**matsôraciyā**	**matsôràtā**

prose

The plural formation as such is entirely regular., A few frozen/lexicalized agent nouns, however, employ other plurals. e.g., **magājiyā / magájiyōyī** 'a madam' f./pl.; **magūdiyā / màsu gūdâ = 'yan gūdâ** 'woman who ululates during festivities' f./pl.; **macîjī / màcîzai** 'snake' (lit. one who bites) m./pl.

°AN: Derivationally, **macîjī** is formed from the verb **cîzā** 'bite' even though in Hausa, snakes do not *bite* but rather *slash*, e.g., **maciji yā sārè ta** 'A snake bit (lit. slashed) her'.

Monosyllabic verbs employ an epenthetic /y/ between the verb root and the suffixal ending, e.g.,

examples

bi follow	**mabiyī / mabiyiyā / mabiyā**	a follower of s.o. (m./f./pl.)
ki dislike	**makiyī / makiyiyā / makiyā**	enemy (m./f./pl.)
shā drink	**mashâyī / mashāyiyā / mashâyā**	drinker, alcoholic (m./f./pl.)

prose

In the above feminine forms, the sequence /iyiyā/ is usually pronounced without the /i/ between the two /y/'s. The floating L tone attaches to the preceding syllable to produce a fall, i.e., **mabiyiyā** → [mabiyyā], **makiyiyā** → [makiyyā].

1.2. Verb stems with -TA

[…]

1.3. Meaning

prose

The basic meaning of an agent noun is someone who customarily does the action of the underlying verb, commonly as a profession, e.g., **madînkī** 'tailor' (< **dînkā** 'to sew'). The semantic connection between the agent nouns and their source words is generally evident, e.g., **ma'àskī** barber < **askè** 'shave'. In some cases, however, these words have a lexicalized meaning that is more specialized and restricted than that of the related verb. Examples:

examples

mabìyī	a follower (esp. religious); younger brother or sister < **bi** follow
maciyī	voracious < **ci** eat
mafàshī (usu. **d'an fashī**)	robber < **fasā** break, shatter; commit robbery
makàdâicī	unique (referring to God) < **kàdaità** sit apart; acknowledge the unity of God
maniyyàcī	an intending pilgrim < ***niyyata** < **niyyā** intention, wish .
marìkī	guardian, foster parent < **rikè** grasp, hold
matâshī	adolescent, youth < **tāshi** rise, grow up

prose

In a couple of special cases, the agent does not denote the doer of the action but rather the one affected by the action. The word **ma'àikī** (< **àikā** 'send') is used in the designation **ma'àikin Allàh** 'the Prophet Muhammad, i.e., the one who was sent by God', cf. **Allàh ma'àikī** 'God (lit. God the sender)'. The dictionaries also give the feminine agent word **makullìyā** with the meaning 'slave-concubine' (i.e., one who is locked up) < **kullè** 'lock'.

function

FIGURE 3.: The discussion of the agentive morpheme *ma-* in Newman (2000) shows a division of formal and functional properties, and a further subdivision in prose parts and example parts.

paragraph, related paragraphs into sections, and related sections into chapters, with possibly some intervening levels (Good 2004). The conceptual unity of a discussion within a grammatical description is typically reflected in typography by white space. Tight coherence is mirrored by little space (e.g. between sentences), while more loose coherence is expressed by blank lines between paragraphs or blank pages between chapters. These organizational blocks thus reflect the semantic structure of the grammatical description. In a book, they are necessarily ordered linearly. However, when discussing the members of a set of morphemes, there is no inherent order. To take the French question words *qui* 'who', *quand* 'when', *quoi* 'what', *comment* 'how', *où* 'where', *pourquoi* 'why', no clear order of discussion suggests itself. The discussion of *qui* is pretty much independent of the discussion of *quand*, and both are independent of the discussion of *où*. The gist of the description does not change if you discuss *qui* before *quoi* or the other way round. The fact that in grammatical descriptions they are found in the sections numbered X.1, X.2, X.3 etc is simply a reflex of the requirement of the linear structure for printing. These numberings correctly indicate the subordination of these concepts to a higher complex of 'question words' (X in the example above), but they incorrectly suggest an inherent order among these items.[8] When creating the semantic markup for grammatical descriptions, we should not be fooled by incidental side effects of printing. However, the hierarchical structure of grammatical descriptions must be recognized. Some phenomena need to be discussed at an abstract level.

To take an analogy from classical zoologic taxonomy, in the family of *Felinae* we find the genera *Lynx, Leopardus, Puma,* and *Felis*, among others. There is surely no inherent order in discussing these genera, but some characteristics are shared among all members, e.g quadripedal, carnivore diet or moustaches. It would be redundant to state these facts at every individual level. They can better be discussed at the superordinate level of *genus proximum*. The same is true of linguistics. A semantic markup of grammatical description must provide for the possibility to state generalizations and sub/superordination. This is not a trivial problem. Here I would like to propose that this can be done by a general description followed by an enumeration of the members of the class with links to more detailed descriptions of the particular members. The XML-structure would be as follows:[9]

(4)
```
<fomp type="formlist" name="Question words">
  <overview>
      <prose>
          Question normally start with the string "Wh".
          An exception is <form> how </form>. They are
          used to express <meaning> requests for
          information </meaning>. Question words normally
          trigger <form> do-support </form>.
      </prose>
  </overview>
  <ul>
```

[8] Good (2004) concurs with the non-linear structure but remarks that the logical independence of these sections may be forfeited for a gain in didactic usefulness. To remain within the French example, the discussion of *quoi* should probably take place before *pourquoi* because the former is a component of the latter.

[9] For reasons of simplicity, I omit the representation of 'illustrative examples/paradigms' which are sometimes used in overview sections (Good 2004).

```
        <li><form> Who </form></li>
        <li><form> What </form></li>
        <li><form> When </form></li>
        <li><form> Why </form></li>
        <li><form> Where </form></li>
        <li><form> How </form></li>
      </ul>
    </fomp>
```

This list structure can be recursive (Good 2004), so that deeper levels of subordination can be represented (free words>Nouns>Common Nouns>Count Nouns). Furthermore, multiple inheritance would also be possible.

As far as the treatment of formal (or semasiological) aspects is concerned, we thus have to distinguish two types of *fomps*: a kind of terminal node of the type "form-to-function" and a superordinate node of the type "formlist". The latter can include links to instances of the former.

The structure of the morphemicon can then be represented as in (5). Note that the linear order of the elements is a coincidence here. The morphemicon is an *un*ordered list, as discussed above.[10]

(5)
```
<morphemicon>
  <fomp type="formlist" name="Question words">
  ...
  </fomp>
  <fomp type="form-to-function" name="who">
  ...
  </fomp>
  <fomp type="form-to-function" name="what">
  ...
  </fomp>
  <fomp type="form-to-function" name="where">
  ...
  </fomp>
  <fomp type="form-to-function" name="why">
```

[10] As an illustration of the unordered nature of fomps, we can take Newman (2000), who lists them in alphabetical order, the following is an excerpt from the table of contents:

- Prepositions
- Pro-Verb *yi*
- Pronouns
- Questions
- Reason and Purpose
- Reduplication

```
    ...
    </fomp>
    ...
    ...
    <fomp type="formlist" name="Demonstratives">
    ...
    </fomp>
    <fomp type="form-to-function" name="this">
    ...
    </fomp>
    <fomp type="form-to-function" name="that">
    ...
    </fomp>
  </morphemicon>
```

5.4 The treatment of examples: Bow, Hughes and Bird Besides the structure of the higher level elements and descriptive prose, the linguistic example is obviously central to the discussion of semantic markup. This area has received a seizable amount of research (Drude 2002, Peterson 2002, Bow et al. 2003), which cannot be fully reviewed here. For the purposes of this paper, I adopt the XML-schema proposed by Bow et al. (2003), given for reference below.

(6)
```
<interlinear-text>
  <item type="title"> The Title</item>
  <phrases>
    <phrase>
      <item type="gls"> A phrasal translation</item>
      <words>
        <word>
          <item type="txt"> Word</item>
          <morphemes>
            <morph>
              <item type="txt"> Morph</item>
              <item type="gls"> Gloss</item>
            </morph>
            <morph>
              <item type="txt"> Morph</item>
              <item type="gls"> Gloss</item>
            </morph>
          </morphemes>
        </word>
      </words>
    <phrase>
  </phrases>
</interlinear-text>
```

This 'raw' example can be further enhanced by information on meta-data (source, links to media files) and additional didactic annotations (constituency, highlighting of important aspects Good 2004).

5.5 Extending formal description: beyond the morpheme In the paragraphs above I have discussed how morphemes can be linked to functions. However, morphemes are not the only meaning-bearing units in language. There are also constructions like *VERB the TIME away* e.g. *dance/waltz/chat the night/evening away* or more concrete *kick the bucket* (Culicover & Jackendoff 2005). The particular meaning of these constructions is more than what is present in their morphemic parts, so that we must assume some meaning stemming from the construction itself (Fillmore & Kay 1993, Goldberg 1995, Croft 2001). Another example is the difference between *John has come* and *Has John come?*. In this case, the relative order of auxiliary and subject indicates whether we are dealing with an assertion or a question. The meaning-bearing units of a language are thus not exclusively atomic, but they can be complex as well (Lehmann 1993). Furthermore, they are not always concrete as in the case of morphemes or idioms but they can also be schematic as in the case of the inversion questions. All this warrants the creation of a space where to discuss the meanings carried by these constructions. Following Goldberg (1995) I call this space *constructicon*.

The morphemicon deals with atomic and concrete elements, while the constructicon deals with schematic elements, which may be abstract or concrete. Both have in common that they deal with segmental material. Yet another complex bearing meaning in language is intonation, which is suprasegmental. The change of falling to rising intonation in the pair *Jim's mother has come.* vs. *Jim's mother has come?* has a predictable correspondence on the meaning side, the change of an assertion into a question. It seems best to treat intonation separated both from morphemes and constructions in a *contouricon* although there are of course some relations (WH-words trigger question intonation etc). The final structure of the morphosyntactic part is then

(7)
```
<forms>
 <morphemicon>
  <fomp type="morpheme" lemma="XX"> ... </fomp>
  <fomp type="morpheme"  lemma="YY"> ... </fomp>
  ...
 </morphemicon>
 <constructicon>
  <fomp type="construction" lemma="A B-C"> ... </fomp>
  <fomp type="construction" lemma="DE=F H G"> ... </fomp>
  ...
 </constructicon>
 <contouricon>
  <fomp type="intonation" lemma="HHL"> ... </fomp>
  <fomp type="intonation" lemma="HLH"> ... </fomp>
  ...
 </contouricon>
</forms>
```

5.6 PHONOLOGY The phonological part of grammatical description is normally structured as follows.

```
(8) <phonology>
      <segments>
        <phonemechart/ >
        <vowels> ... </vowels>
        <consonants> ... </consonants>
      </segments>
      <phonotactics> ... </phonotactics>
      <stress> ... </stress>
      <!-- <intonation> ... </intonation> -->
```

As discussed above, I propose to treat intonation as something which does not merely distinguish meaning (like phonemes) but which carries a meaning of its own, more like morphemes (cf. Mosel 2006). Therefore, it can be meaningfully treated in the context of form-meaning-pairs, and there is no need to repeat the information in the phonological parts (although there should obviously be links between the two). This is why this element is commented out in (8).

The remaining content in the phonological domain belongs to the domain of 'distinguishing meaning'. This cannot be discussed in the context of form-meaning-pairs. The schmematization of this part will be left as a topic for future research.

5.7 SEMANTICS: FORM-MEANING-PAIRS ORDERED ACCORDING TO FUNCTION Above, I have discussed the structures we find in form-meaning-pairs based on morphemes and other forms. This approach is called the form-to-function or semasiological approach. Let's call this perspective form-based form-meaning-pairs, or *fo-fomps* for short. It is possible to take the converse approach, i.e. function-to-form or onomasiological (von der Gabelentz 1891, Jespersen 1924). This approach is the one which is generally relevant in typological work, although it is less prevalent in extant grammatical descriptions (Lehmann 1980, Comrie 1998, Lehmann 1998, 2004b, Schultze-Berndt 1998, Cristofaro 2006, Mosel 2006, Payne 2006, Zaefferer 2006), a notable example being (Willett 1991). Figure 4 shows the table of contents of Willet's description of Southeastern Tepehuan

This is in many ways the mirror image of the former approach. Instead of taking a form and looking at the meanings it can express or the functions it can fulfill, we take a function and look at the forms it can be instantiated by. Let's call this perspective function-based form-meaning-pairs or *fu-fomp*. The division in prose parts and lists of examples is the same as above.

An illustrative example of the structure of a fu-fomp is given below in (9). Note the similarity to example (2) above.

```
(9) <fomp type="function-to-form" lemma="Comparison">
      <prose>
        The <function> comparative degree </function> of
        adjectives can be expressed by the suffix <form>
        -er </form> or by the particle <form> more </more>
```

FIGURE 4.: Excerpt from the table of contents of Willett (1991). For reasons of space, only selected subsections are shown.

```
    </prose>
    <examples>
      <example> Mary is taller than John </example>
      <example> Mary is more intelligent than
      John </example>
    </examples>
    <prose>
      As we see in the example above, short adjectives
      form the comparative with <objectlanguage>
      -er </objectlanguage> while longer adjectives take
      the particle <objectlanguage> more </objectlanguage>.
    </prose>
  </fomp>
```

A more real-life example is given in Figure 5, which shows the discussion of the function of comparison of adjectives in Lakota. This function can be instantiated by three different constructions. After an initial overview of what this section is about, three different constructions which can be used to convey this meaning are discussed. These are a) an adverb meaning 'more', b) several other types of words with a rough meaning of 'surpass' and finally c) a contrastive juxtaposition of the type 'X is good and Y is bad'.

Given that the readers of grammatical descriptions are normally expected to have a basic knowledge of the world, the introductory portions of fu-fomps tend to be short. There is no need to belabour the intended meaning of the function called 'comparative degree' or 'temporal reference prior to speech act' as this is pretty much self-evident from the naming. In some more involved domains involving less familiar concepts like e.g. the paucal, the introduction can be longer and illustrate the functional domain at hand in more detail. This

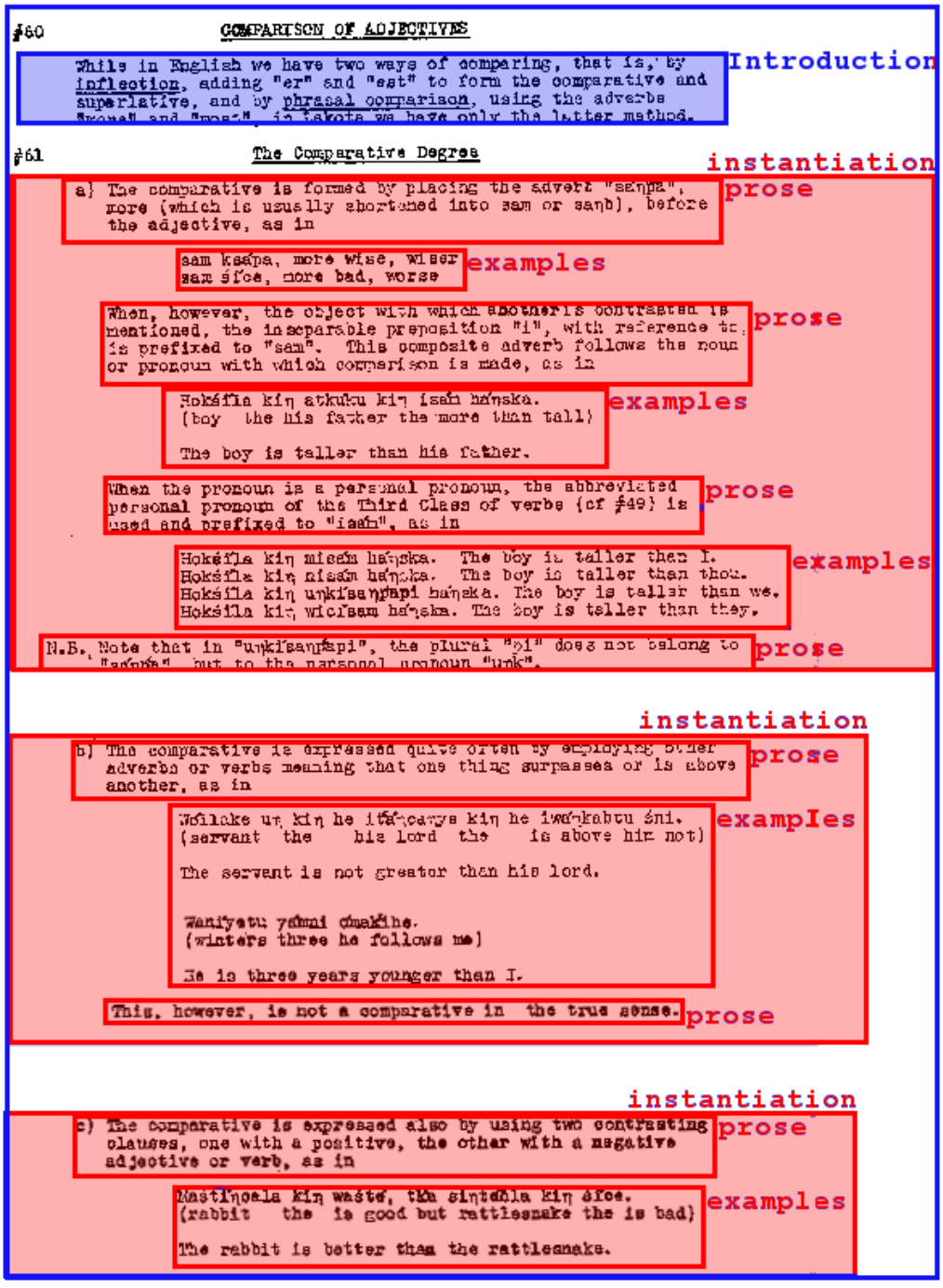


FIGURE 5.: The discussion of the function 'Comparison of Adjectives' in Lakota in Buechel (1939), with three forms instantiating this function.

is especially true for semantic distinctions presumed unfamiliar to the average reader, like alienability, evidentials, or the paucal mentioned above.

In a function-to-form approach, additional contrastive information can be provided about shades of meaning, frequency or register. This information is less commonly found in form-to-function approaches. Figure 6 from Willett (1991) shows the description of a function and two formal instantiations thereof. Crucially, the two formal strategies come from different domains: the first one is a prefix (morphology) while the second one is a particle (syntax). In a form-to-function approach, the functional relatedness of these forms would have been difficult to convey. Furthermore, the two strategies can now be compared as to their felicity in different contexts, and their overall frequency. Without the functional *tertium comparationis* of 'Intention' spelled out, this information would have been very difficult to find in the grammar.

5.8 **Extending functional description** I have shown above that different types of fo-fomps exist, namely those which belong to the morphemicon, the constructicon, and the contouricon. In what concerns fu-fomps, a similar division exists. We can distinguish meaning components which are purely semantic and relate to the communicated content. Examples are participants, events, space, and time as in *John ate a cake at the party at midnight*. These meaning components can be grouped in a *semanticon*. This purely semantic information is different from meaning components like topic and focus, which do not belong to the propositional content. An example would be the difference between *John came* and *It was John who came*. These sentences communicate the same semantic content and are truth-equivalent. Yet, there is a difference in information structure in that in the second sentence, the hearer is already expected to know that an act of coming occurred, which is not the case in the first sentence. These components of meaning which belong to information structure or discourse pragmatics can be discussed in a *discoursicon*. Speech acts are yet another type of function which is outside of both semantics proper and discourse. An example would be a request like *Please do come, John*. I will collect this interpersonal type of information in a *pragmaticon*. This division mirrors the layered structure of the clause as found in a number of contemporary grammatical theories like Role & Reference Grammar (Foley & Van Valin 1984, Van Valin & Lapolla 1997) or Functional Grammar (Hengeveld 1989, Hengeveld & Mackenzie 2008). We can add this structure to the general outline of grammatical descriptions (10).

(10)
```
<forms>
 <morphemicon>
  <fomp type="morpheme" lemma="ab"> ... </fomp>
  <fomp type="morpheme"  lemma="def"> ... </fomp>
 </morphemicon>
 <constructicon>
  <fomp type="construction" lemma="A B-C"> ... </fomp>
  <fomp type="construction" lemma="DE=F H G"> ... </fomp>
 </constructicon>
 <contouricon>
  <fomp type="intonation" lemma="HHL"> ... </fomp>
  <fomp type="intonation" lemma="HLH"> ... </fomp>
```

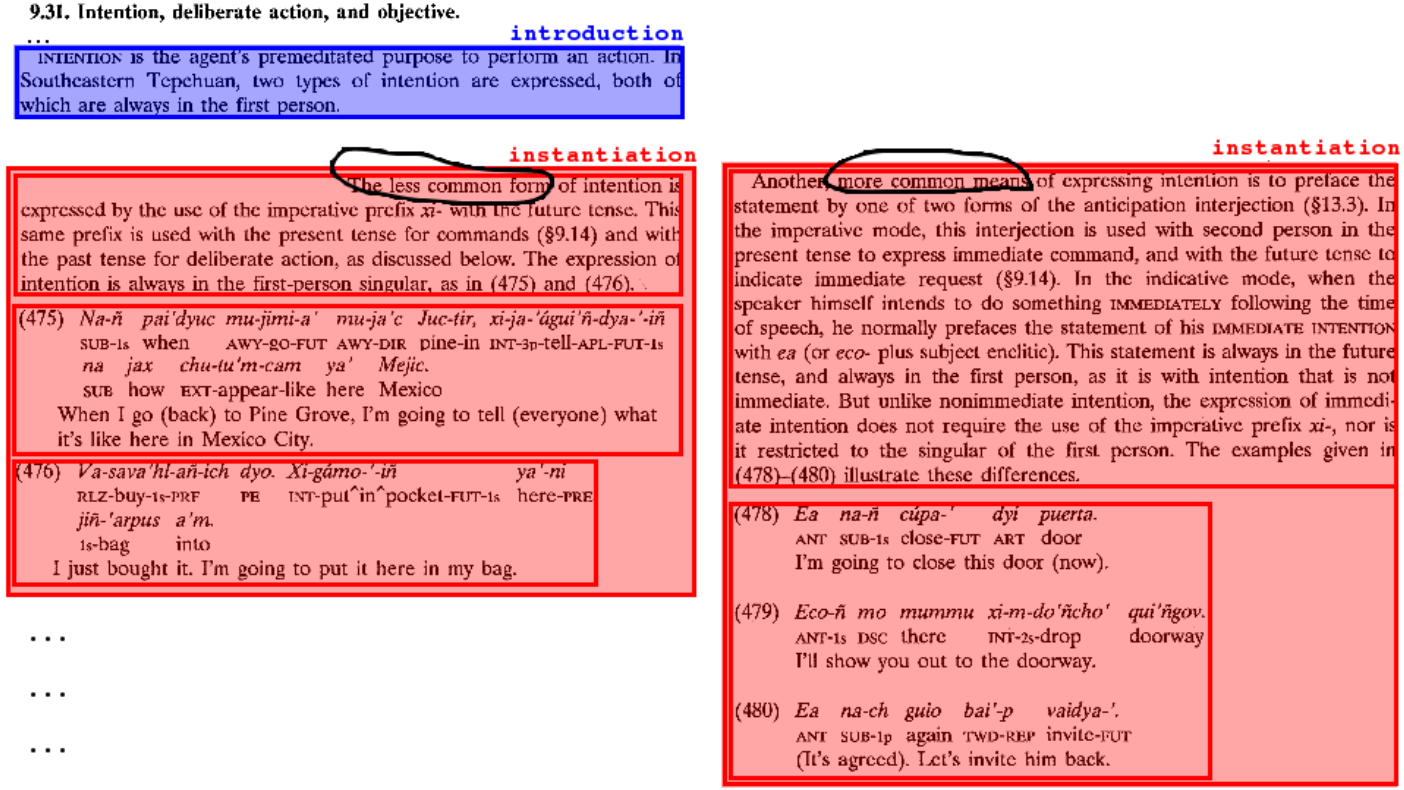


FIGURE 6.: A function-to-form description of 'Intention' in Tepehuan (Willett 1991).

```
 </contouricon>
</forms>
<functions>
 <semanticon>
  <fomp type="semantics" lemma="space"> ... </fomp>
  <fomp type="semantics"  lemma="kin"> ... </fomp>
 </semanticon>
 <discoursicon>
  <fomp type="discourse" lemma="argument focus"> ... </fomp>
  <fomp type="discourse" lemma="new topic"> ... </fomp>
 </discoursicon>
 <pragmaticon>
  <fomp type="pragmatics" lemma="requests"> ... </fomp>
  <fomp type="pragmatics" lemma="insults"> ... </fomp>
 </contouricon>
<pragmaticon>
```

A more extensive subdivision into 13 subcategories of meaning can be found in Lehmann (2004a).[11] These subcategories can be partitioned among the semanticon, discoursicon and pragmaticon, which will not be formalized here.

5.9 COLLECTIONS OF FU-FOMPS Like fo-fomps in (4), fu-fomps can also be arranged hierarchically, for instance the hierarchy

(11) Expressing time > Expressing internal temporal structure > Expressing imperfective aspect.

One can state general observations at the higher levels of the hierarchy ("Tense and aspect are nearly always expressed by prefixes") and more particular observations lower down in the hierarchy ("Progressive aspect can be expressed by *papu-* or by *pipo-*")

(12)
```
<fomp type="funclist" name="Expressing time">
  <overview>
      <prose>
          Expressions of time cover lexical solutions
          like <objectlanguage> aujourd'hui </objectlanguage>
          <gloss> today </gloss> or <objectlanguage>
          hier </objectlanguage> <gloss> yesterday </gloss>.
          When time is expressed by bound morphemes, these
          are normally <form> suffixes<form>. This is true
          for both tense and aspect.
      </prose>
  </overview>
```

[11] Apprehension and nomination, concept modification, quantification, reference, possession, space construction, predication, design of situations, temporal orientation, illocution and modality, contrasting, nexion, articulation of discourse

```
    <ul>
      <li><meaning> Expressing tense  </meaning></li>
      <li><meaning> Expressing aspect </meaning></li>
    </ul>
  </fomp>
```

What has been said above about collections of fo-fomps applies *mutatis mutandis* to collections of fu-fomps as well.

5.10 **INTERACTION OF FO-FOMP AND FU-FOMP** Mosel (2006) notes that an ideal grammatical description could actually be required to state everything twice: once from a formal perspective and again from a functional perspective. A recent grammar which does precisely that is Nordhoff (2009). The table of contents for the formal and the functional part are given in figure 7.

The diligent reader will have noticed that the fo-fomp in example (2) and the fu-fomp in example (9) contain some additional markup. This markup can be used to link the form-to-function (semasiological) description with the function-to-form (onomasiological) description, a common desideratum for electronic grammars (Comrie 1998, Lehmann 1998, Zaefferer 1998, Mosel 2006, Nordhoff 2008). I will illustrate this with a fragment of the grammar of French, namely question formation.

In French, there exist three principal ways to request information from the hearer: rising intonation contour, a question formative *est-ce que*,[12] and inversion. These three patterns are illustrated in (14). (13) gives the declarative sentence for comparison.

(13) *Elle danse.*
She dances
'She dances/is dancing'

(14) a. Elle ↗ danse ?
b. Est-ce qu'elle danse?
c. Danse-t-elle?
'Does she dance/Is she dancing?'

We see that there is a many-to-one relation form form to function, and a one-to many relation from form to function. We can illustrate this as in Figure 8.

At closer scrutiny, we find that inversion is used for other functions as well, for example with coordination as in (15).

(15) *..., aussi chante-t-elle bien.*
also sing-link-she well
'..., and also does she sing.'

[12] For the ease of discussion, I essentially treat *est-ce que* as unanalyzable here. It is true that this introducer can be segmented into *est* 'is', *ce* 'this' and *que* 'that', but the construction has grammaticalized to such an extent that there is little awareness of the internal constituency. This can also be seen from the fact that an authortitative reference grammar of French (Grevisse & Goosse 1995) treats this construction as basically monomorphemic. The term 'introducer' ('introducteur') is also taken from this work.

Verbs
Nouns
Adjectives
Adverbs
Copula
Personal pronouns
Interrogative pronouns
Deictics
Quantifiers
Numerals
Interjections
Modal particles
Negative particles
Other particles
Conjunctions
Classifiers
Affixes
Simple clitics
Bound words
Nominal and verbal morphology
Verbal predicates
Existential predicate
Modal predicate
Nominal predicates
Circumstantial predicate
Adjectival predicate
Noun phrases
Postpositional phrases
Main clauses
Relative clause
Conjunctive participle clause
Purposive clauses
Subordinate interrogative clauses
Supraordination
The position of adjuncts
Reported speech
Agreement

Particpants
Participants of different entity orders
. Participant roles
. Unknown participants
. Modifying participants
Predication
. States
. Events
. Causation
Modification
Space
. Figure-ground relations
. Indicating spatial orientation
Time
. Figure and ground
. Phasal information
. Aspectual structure
Quantification
Modality
Conditionals
Gradation
Comparison
Possession
. Assertion of the possessee
. Possession of abstract concepts
. Assertion of the possessor
Negation
Kin
Referents and reference
Topic
Presupposition and assertion
Canceling implicatures
Parsing
Speech acts
Blending in the social tissue

FIGURE 7.: The formal (left) and functional (right) table of contents of Nordhoff's grammar of Upcountry Sri Lanka Malay.

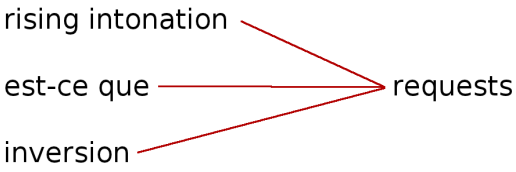


FIGURE 8.: Many-to-one relations of form-meaning pairs

There is thus a many-to-many relation between form and function in language (Noonan 2006) as shown in Figure 9.

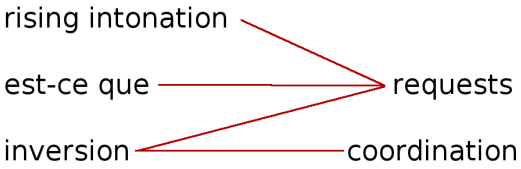


FIGURE 9.: Many-to-one relations of form-meaning pairs

This relation can be expressed by a set of fo-fomps and fu-fomps as follows.[13]

```
(16)  <fomp type="morpheme" lemma="est-ce que">
        <formaldescription>
          <prose>
            The introducer <form> est-ce que </form>  with
            the literal meaning <gloss> Is it so
            that ... ? </gloss>. In front of a following
            vowel, the form is <objectlanguage> est-ce
            qu'</objectlanguage>. Both forms are shown in
            the following examples.
          </prose>
          <examples>
            <example> [example with est-ce que]</example>
            <example> [example with est-ce qu']</example>
          </examples>
        </formaldescription>
        <functionaldescription>
```

[13] In order to not complicate the example further, I dispense with the difference between universal conceptual categories like 'question' and cross-linguistically common instantiations thereof, i.e. 'interrogative sentence' (but see Lehmann 1993). This distinction is important and should be reflected in markup used for grammatical descriptions. However, in the context of this paper, it would incur too much theoretical overhead and would obscure the main line of argumentation. Future publications will explicate the relation in more detail than what can be covered here.

```
    <form> Est-ce que </form> is used for <meaning>
    questions </meaning>
  </functionaldescription>
</fomp>

<fomp type="contour" lemma="H%">
  <formaldescription>
    <prose>
      The rising contour has a high tone target on the
      last syllable.
    </prose>
    <examples>
      <example> [example with high tone target]</example>
    </examples>
  </formaldescription>
  <functionaldescription>
    This contour is used for <meaning> question
    formation </meaning>.
  </functionaldescription>
</fomp>

<fomp type="construction" lemma="Inversion">
  <formaldescription>
    <prose>
      In the <form> Inversion Construction</form>, the
      subject is repeated after the verb. Nominal subjects
      remain in front of the verb but pronominal subjects
      are deleted.
    </prose>
    <examples>
      <example> Marie danse-t-elle?</example>
      <example> (*Elle) Danse-t-elle?</example>
    </examples>
  </formaldescription>
  <functionaldescription>
    <prose>
      The <form> Inversion Construction</form> is used
      for <meaning> question formation </meaning> and
      for <meaning> coordination </meaning>.
    </prose>
    <examples>
      <example> Chante-t-elle? </example>
      <example> Aussi chante-t-elle bien </example>
    </examples>
  </functionaldescription>
```

```
</fomp>

<fomp type="Speechacts" lemma="Requests">
  <overview>
    <prose>
      A <meaning> request </meaning> is used to elicit
      information from the addressee.
    </prose>
  </overview>
  <instantiations>
    <prose>
      Three strategies
      can be used to form requests. These are <form>
      rising intonation </form>, <form> preposing the
      introducer <objectlanguage> est-ce
      que </objectlanguage></form>, and <form>
      inversion</form>.
    </prose>
    <examples>
      <example>  Elle danse?</example>
      <example>  Est-ce qu'elle danse danse?</example>
      <example>  Danse-t-elle?  </example>
    </examples>
    <prose>
      The first example is the least formal, the middle
      one is quite neutral, while the third one is decidedly
      formal and pertains to the written language.
    </prose>
  </instantiations>
</fomp>
```

This example models the many-to-many relations between form and function in a transparent way. The most relevant parts in the context of this discussion are <form> </form> and <meaning> </meaning>, which can be made to point to the page where the relevant formal or functional phenomenon is discussed in more detail. The reader might have noticed that the text between the tags varies and is not drawn from a restricted vocabulary. While there might be a possibility to avoid this arbitrariness in future descriptions, this is not possible when retrofitting the schema on extant descriptions. Therefore, the precise target of the form-links and the meaning-links has to be specified. So instead of

(17) `<form> preposing the introducer <objectlanguage> est-ce que </objectlanguage></form>`

we should have something like

(18) `<form target="est-ce que"> preposing the introducer <objectlanguage> est-ce que </objectlanguage></form>`

Note that the target `"est-ce que"` matches the lemma tag of `<fomp type="morpheme" lemma="est-ce que">`.

In the same vein, we can rewrite

(19) `A <meaning> request </meaning> is used to elicit information from the addressee.`

as

(20) `A <meaning target="Requests"> request </meaning> is used to elicit information from the addressee.`

These targets are ideally linked to an ontology to make the references clear and consistent and facilitate cross-linguistic searches (Farrar & Langedoen 2003). This will not be pursued here for reasons of space, but see Good (2004, this volume) for ideas how this can be done.

6 Interaction with the user As Weber (2006) remarks, grammatical descriptions are never finished. New insights are continuously gained.[14] When a grammatical description is made available electronically, the findings can be updated. Nordhoff (2008) discusses the advantages of and requirements for electronic grammar writing. An aspect not discussed in Nordhoff (2008) is the possibility for users to add tags to pages of an electronic description. These tags can be either arbitrary like `Compound`, `Important`, `SimilarToWarlpiri`, `Grammaticalization` or `V-Movement`. This kind of tag would have to be distinguished from a set of tags drawn from a closed restricted vocabulary. One possibility would be to rely on established schemas like the LDS questionnaire, so that tags like `LDS_2.3.4` would have a clear and defined meaning. Another obvious provider for a restricted and controlled set of vocabulary would be the GOLD ontology (Farrar & Langedoen 2003). If grammatical descriptions manage to draw a critical mass of tagging users, tag clouds can give a quick overview of the aspects of a certain page which the majority of the users find particularly relevant (cf Bouda & Cysouw this vol.).

7 Schematization I have discussed the overall structure of a grammatical description above, including frontmatter, mainmatter and backmatter. The mainmatter was analyzed as consisting of a background part, a part for segmental phonology and two interdependent collections of form-meaning-pairs ('fomps'). The first one is based on the form-to-function or semasiological approach to grammatical analysis, while the second takes the converse onomasiological approach, function-to-form. The form-based and function-based fomps show similar structure. Both consist of alternating parts of prose and examples (Figure 10). These findings can be described in the RelaxNG schema given below (parts irrelevant in the context of this paper are treated as unstructured "texts" to keep the size of the schema within bounds).

[14] See Comrie (1998), Cristofaro (2006), Mosel (2006), Payne (2006), Rice (2006) and Zaefferer (2006) for similar observations.

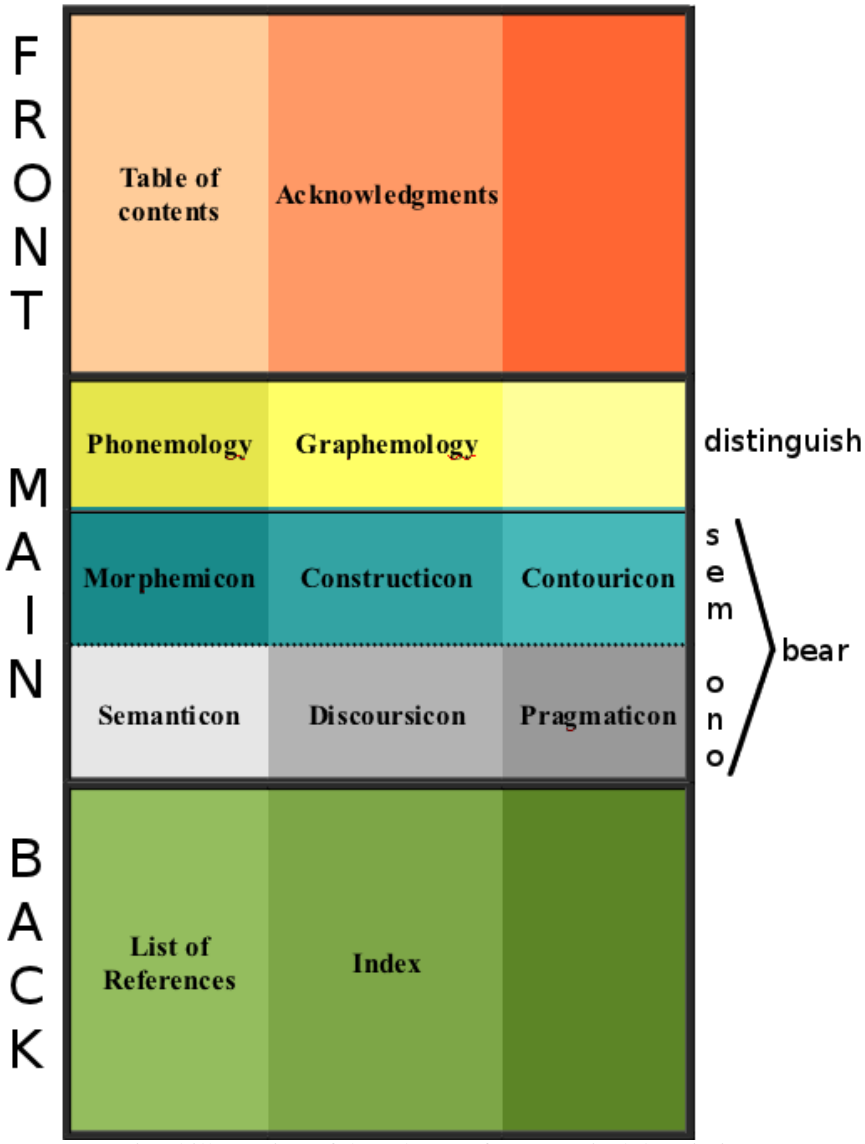


FIGURE 10.: Visual illustration of the schema of grammatical descriptions.

(21)
```
GD =  element gd { Frontmatter,Mainmatter,Backmatter }
Frontmatter = element frontmatter { TOC, LOF, LOT, LOA, Acknowledgments }
Backmatter = element backmatter { References,Index }
Mainmatter = element mainmatter { Phonemology, Semasiology, Onomasiology }

Phonemology = element phonemology { Phonemicon }
Semasiology = element semasiology { Contouricon, Morphemicon, Constructicon }
Onomasiology = element onomasiology { Semanticon, Discoursicon, Pragmaticon }

Phonemicon = element phonemicon  { text }
Contouricon = element contouricon  { Fo-Part }
Morphemicon = element morphemicon  { Fo-Part }
Constructicon = element constructicon  { Fo-Part }

Semanticon = element semanticon  { Fu-Part }
Discoursicon = element discoursicon { Fu-Part }
Pragmaticon = element pragmaticon { Fu-Part }

Fo-Part = element fo-collection { (Fo-Collection|Fo-Fomp)* }
Fo-Collection = element fo-list { Tags,  Prose, Examples, Formlinklist }

Fu-Part = element fu-collection { (Fu-Collection|Fu-Fomp)* }
Fu-Collection = element fu-list { Tags,  Prose, Examples, Funclinklist }

Examples = element examples { Example+ }

Fo-Fomp = element fo-fomp { Tags,  Overview, Formaldescription, Functionaldescription }
Formaldescription = element formaldescription { (Prose|Example)* }
Functionaldescription = element functionaldescription { (Prose|Example)* }

Fu-Fomp = element fu-fomp { Tags,  Overview, Instantiations }
Instantiations = element instantiations { (Prose|Example)* }

Overview = element overview { text }
Prose = element prose { text }

Example = element example { Tags,  Bowhughesbird }
Bowhughesbird = element bowhughesbird { text }

Formlinklist = element formlinklist  { Formlink+ }
Funclinklist = element funclinklist  { Funclink+ }

Formlink = Link
Funclink = Link

Link = element link { attribute name { text }, attribute target { text } }
Tags = element tag { attribute name { text } }*

TOT = element tableofcontents { text }
LOF = element listoffigures { text }
LOT = element listoftables { text }
LOA = element listofabbreviations { text }
Acknowledgments = element acknowledgments { text }
References = element references { text }
Index = element index { text }
```

8 Conclusion and outlook This paper has analyzed the semantic structure of grammatical descriptions and shown that in the domain of form-meaning pairs, the interaction between the semasiological and the onomasiological approach can be formalized in a RelaxNG schema. Grammars structured along this schema have a number of advantages. First, the schema encourages encapsulation of the descriptive content. The descriptive content in each fomp should be independent of the surrounding fomps. If the schema is adhered to, the constraint of linearity disappears. The elements are self-contained, which allows for addition and modification of elements without affecting the overall structure (terminological consistency remains an issue of course). This means that grammars can be written and published in an incremental heap-like way, making new insights available to the general public as they are gained (cf. Weber 2006, Good this volume). Furthermore, the basic advantages of structured text obtain, e.g. semantic searches, extraction, modification, differential presentation (Maxwell this volume).

The schema proposed here is designed to be compatible with recent structuring proposals in other domains of grammar, namely Bow et al. (2003) and Good (2004). Further work in analyzing the structure of grammatical descriptions needs to be done. Issues for further theoretical work are: the structure of phonological descriptions, the nature of tags and links, and the implementation of a controlled vocabulary for certain fields through an ontology. As far as practical applications are concerned, the schema will have to be measured against the actual requirements of future and past grammars. Is it possible to use this schema when writing a grammar, and is it possible to retrofit this schema on an existing grammar? As for the former question, first results are positive. Nordhoff (2009) is a descriptive grammar of a previously undescribed language, Sri Lanka Malay. While this grammar is not in XML-format yet, it was designed with the application of the above schema in mind. As such it contains a formal part and a functional part, which are roughly structured as outlined above. Furthermore, the individual sections in the two parts are parallel to fo-fomps and fu-fomps. The conversion process of the manuscript to XML is currently under way and looks promising. Retrofitting the schema on legacy descriptions is a more difficult task. The book has to be split into independent fomps. Depending on whether the author adhered to a strict separation of formal and functional discussion (e.g. Seiler 1985), the task is more or less easy. Resolving interparagraph dependencies (*as demonstrated in the last paragraph, as shown below, contrary to what was said in the preceding section* etc) will probably be a problematic issue in splitting the grammatical description into independent chunks on which the schema can be applied. In a first step, retrofitting will be done manually, but in a second step, semi-automatic analysis of the structure of grammatical descriptions remains a goal. Extraction tools like Lewis (2006) are probably a worthwhile domain to investigate for these prospects.

The ultimate goal would be to have an online repository of all existing grammatical descriptions which are converted to XML. These could be queried in a semantic fashion. The query would yield all the descriptive content of the selected grammars about a particular domain, a very useful feature for large sample typology. While there is still a very long way to go, the GALOES platform (Nordhoff 2007b,c,a) is aimed at supporting language describers in writing XML-based grammars. Descriptive departments in several European countries have expressed interest in collaboration. In the long run, this should assure that future grammatical descriptions comply with the schema. As for legacy descriptions, the next step will

be an analysis of the 10,000 electronic grammars collected by Harald Hammarstöm to see how far automatic extraction procedures can get us. This topic will be treated in future papers.

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Language description and hypertext: Nunggubuyu as a case study

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Any reasonably complete description of a language is a complex object, typically composed of a grammar, a dictionary, and a text collection with internal relationships that can be represented as hyperlinks. The information would be fully searchable, links between text and media could be implemented, and the presentation would be based on a well-defined data structure with advantages for archiving and reusability.

We present a small fragment from Heath's Nunggubuyu text collection with links to parts of the other elements of the description to demonstrate the benefit which this approach can bring. This initial step involves a certain amount of hand-coding but establishes a basis for the necessary data structure which will then be used in a second phase where we develop techniques for the automatic processing of scanned versions of Heath's work.

Grammatical descriptions written with the kinds of structure we are developing, or capable of being converted to that structure (while being 'born digital') are likely to be in short supply. Presentations of old materials in new formats will inform new electronic grammars, and help gain the acceptance of the linguistic community for preferred formats.

1 Introduction Any reasonably complete description of a language is a complex object. Traditionally, such works are divided into various components: a grammar, a dictionary and a text collection, the so-called Boasian trilogy. But of course these are really highly interrelated. For example, a single entry in the dictionary is of little value without the general information about words of that class which can be found in the grammar, and any point made in the grammar may be hard to grasp without extensive exemplification from texts. Boas himself was well aware of this fact:

> We have vocabularies; but, excepting the old missionary grammars, there is very little systematic work. Even where we have grammars, we have no bodies of aboriginal texts .... [I]t has become more and more evident that large masses of text are needed to elucidate the structure of the languages (Boas 1917:1)

As Woodbury (2011:163) comments on this passage: "All three were interrelated parts of a documentary whole, treating, in different ways, overlapping empirical domains".

The interrelatedness of the various components discussed above immediately suggests that hypertext would be a better means of presentation and additional benefits could come from making the grammatical description a multimedia object, rather than a text object. Examples could be heard in the original sound recorded by the researcher, or even seen as video clips where such presentation would aid the consumer (for example, where gesture added an important element of meaning to the utterance). In addition to the improved accessibility of the descriptive information, such presentation would bring the consumer much closer to the primary data, actual language in use, and therefore multimedia language description would increase substantially the standard of accountability in linguistics. However, the standard paper and ink presentation of grammatical description has an established linear format which is not suitable for the new medium.

Most grammatical descriptions published in book format follow more or less closely a standard format. The presentation begins with background information on the language and its speakers, the relationship of the language to other languages, and a survey of previous research. The description proper then follows, moving through phonetics and phonology (the sounds of the language and how they are organized into a system), morphology (word-formation processes), and clausal syntax. Some discussion of syntax above the level of the individual clause and of textual organization may follow. If example texts are included in the volume, as is common, they will come after this, with word lists after them (Nordhoff this volume). The organization of a grammar in this style is linear, that is, one sort of information is presented before another. And the linearity is to a large extent well-motivated. It is generally not easy to understand the morphological processes of a language before one understands the phonology; it is hard to understand syntax (combinations of words) before one understands morphology (word-formation). Linearity of presentation is also a consequence of the medium. Paper and ink objects are read normally in sequence; even if one reads only a short section of a larger work, one starts at a particular place and reads on in sequence for as long as necessary. Hypertext, on the other hand, is a non-linear medium and the metaphor of a web is entirely appropriate for such presentation. As already mentioned, hypertext has clear benefits for the presentation of grammatical description, but it is desirable that at least some of the linear logic of the paper and ink model should be accessible in the new medium.

We wish to explore the possibilities of presenting grammatical description in an electronic form while maintaining a strong link with the traditional mode of presentation (cf Drude this volume). In order to do this, the ideal material to work with is a description presented in book format which nevertheless makes extensive use already of the interrelatedness of its various components. Jeffrey Heath's description of Nunngubuyu fits these criteria. The following section briefly describes this work and illustrates its value as an exemplar for developing richly interlinked language description for electronic presentation. Section 3 of this paper discusses our approach to encoding the source texts to make them accessible for online presentation and section 4 outlines our plans for further development of this project. Finally, in section 5, we turn to some design issues in electronic grammaticography as we view them in light of our work on Nunggubuyu.

FIGURE 1.: Arnhem Land, showing the location of Nunggubuyu

2 HEATH'S DESCRIPTION OF NUNGGUBUYU Nunggubuyu (ISO639-3: nuy, also known as Wubuy) is a non-Pama Nyungan language spoken in Arnhem Land, Australia (see Figure 1).

Heath's description of the language was published in three volumes: texts (Heath 1980), dictionary (Heath 1982) and grammar (Heath 1984). The three volumes are very explicitly interlinked: the grammar volume does not include examples sentences, but a list of references to the text volume is given with each grammatical point and a similar procedure is followed in the dictionary (see Figure 1). The dictionary entry which is given in Figure 22(a) refers to Text 43, section 4, line 1 as an example of the lexeme in question. This section of text is given in Figure 22(b), and the relevant word form can be seen in the first line. Figure 22(c) shows an excerpt from the grammar volume. From the fourth line of the excerpt, a list of text references which illustrate the point described is given; the fourth of these references (at the start of line 5) refers to the text fragment in 22(b) (43.4.3) and the relevant words can be seen in the third line of text.

The reader should bear in mind that we have carefully extracted these relevant sections from three separate books; in order to follow Heath's description to this level of detail requires manipulating and navigating three discrete physical objects.

dhan^{g}gid! Rf to chop. 16.14.3, 43.4.1, 43.6.4.
Associated with verb =lha- 'to chop'.

(a) Dictionary entry from Heath (1982)

43.4 wu=wayama-n^{g}i-yaj mari dhan^{g}gid! adaba ∅=lhi-n^{y},
as it proceeded$_{c}$ and chop then it chopped it$_{p}$

2 ana-ran^{g}ag, ∅=madhari-n^{y} ∅=madhari-n^{y} ∅=madhari-n^{y}, yin^{g}ga
wood it chopped it$_{p}$ nearly

wu-ragar=bayama-n^{g}i mari n^{g}ijan^{g} wurugu dulmurg!,
it went along forcefully$_{c}$ and more later run

4 wini=wilbili-n^{y} arwagarwar-ala-aj,
they (MDu) flew$_{p}$ around on top

It (devil) came along and began to chop down the tree. It was chopping and chopping. It (tree) was about to crash down, but then they (two) flew away. (They flew) around up high.

(b) Excerpt from Heath (1980)

This particle can combine with other particles. We mentioned /mari wurugu/ and /wurugu n^{g}a/ in the previous section (it is likely that /n^{g}a wurugu/ also occurs). We can cite /n^{g}ijan^{g} wurugu/ (cf. next section) 'again later' or 'more later' 21.9.1, 21.10.1, 33.1.2, 43.4.3 (with preceding /mari/), 43.5.2/4, 52.5.2/3, 163.19.2/3, showing this order to be consistent. There is also an ex. of /wurugu yin^{g}ga/ (cf. §12.7) 'later' (with anticipation nuance) 71.2.4.

Additional exx. of /wurugu/ are 7.6.1/2, 13.13.4, 37.2.4 (if not mistranscribed), 47.12.7, 55.9.2, 69.5.1, 69.7.4/6, 71.18.1, 73.5.5, 106.3.1/2, 116.8.2, 143.10.3, 157.7.2, 161.1.4, 161.3.4, 161.20.2, 161.32.4, 162.7.5, 162.14.1, 163.14.2, 165.1.1.

A competing form (not a particle) is /an-uba-ni:-'la-wala/ 'after that' (§7.8, §7.31).

(c) Excerpt from Heath (1984)

FIGURE 2.: Examples of linking between Heath's volumes

Heath was very clear in his intention in following this practice. He emphasised in the introduction to the grammar volume that he was concerned with documentation:

> These textual citations serve several purposes. When attached to a fully cited Nunggubuyu ex[ample], they have basically a documentary value – the reader is assured that the ex[ample] is from a real text, and a reader wanting to know more or having doubts about the analysis can find it and analyse it. [...] In this way, we take maximal advantage of the published texts (especially NMET*) achieving a far higher level of documentation than is observable in other reference grammars." (Heath 1984:4) (*NMET = Heath 1980)

And with accountability (see also Maxwell, this volume):

> My concern with documentation reflects my own sad experiences as a reader of other linguists' grammars, which have almost never provided me with the information I wanted to undertake my own (re-) analysis of the language in question. It also reflects my experience that most published grammars are based on material obtained in unreliable direct-elicitation (sentence-translation) sessions [...] I have no confidence whatever in such data, since my own early 'data' of this type often turn out to be seriously wrong. (Heath 1984:5)

However, these aims came at a price in terms of useability. In the course of otherwise extremely positive comments, two reviewers drew attention to the complexity of the work:

> "Unfortunately, F[unctional] G[rammar of] N[unggubuyu] is a very demanding work, both because of the inherent complexity of the language and because it requires the reader to make constant reference to the text volume." (Blake 1985:310)

> "the work is particularly difficult to read. H[eath] makes no pedagogical concessions to the reader. One must look up the attestations for every major grammatical point in another volume." (Haiman 1986:654-655)

The linking structure which Heath included as an essential element of his description of Nunggubuyu lends itself naturally to treatment as hypertext links between documents,[1] and we suggest it can serve as a first model for the structure of grammatical description in this format. For this model to be usable with new language data, it is necessary to establish encodings which, on the one hand, can be easily transformed into presentation formats while, on the other hand, still being formats with which linguists can work.

3 Encoding issues

[1] The fact that Heath's original recordings from his fieldwork are archived accessibly at the Australian Institute of Aboriginal and Torres Strait Islander Studies is an additional factor in our decision to work with this description.

3.1 ORTHOGRAPHY Heath uses a practical orthography to represent Nunngubuyu. This includes digraphs <n^{y}> and <n^{g}> to represent palatal and velar nasals respectively, and underlining of <t,d,r> to represent retroflex consonants. This system differs slightly from the system favoured by the speaker community today. Our aim is to preserve Heath's orthography and to use transformations to produce output in the current orthography where this is required. As Unicode does not treat underlined characters as unique glyphs, in basic formats we treat retroflex consonants as sequences of an underscore followed by the relevant character (which can be rendered by U+0331, the 'combining macron below' when necessary).

3.2 INTERLINEAR GLOSSED TEXT (IGT) IGT is a common and extremely useful representation of bilingual text, capturing the complexity of the structural elements in the focus language in a morphemic level of annotation and providing a sentence-by-sentence translation at the free gloss level. Despite its ubiquity in linguistic description and despite theoretical modelling of various kinds[2] there is still no standard format for IGT that we could adopt in this model of linked Nunggubuyu data. The most common tool for creating IGT is probably *Toolbox* with the benefit of lookup functions that allow parts of a corpus to be linked to the lexicon, to concordances and to specific wordlists (see e.g., Hirzel 2001). The successor to Toolbox, *FieldWorks,* addresses issues of interlinking by use of an underlying database, with the possibility of export to XML which may capture the relationships, but, if so, it is not clear to us what the schema is that allows these relationships to be encoded in the text.

Typecraft[3] is a system for presenting interlinear text online served from an underlying database and uses Mediawiki, as does Nordhoff's 2008 GALOES[4] which constructs an interlinked grammatical description. While these are ways of representing IGT using XML, there is no standard schema that provides a means for creating and linking between instances of IGT. Thus, for example, the online database of interlinear text (ODIN[5]) which searches the web for likely examples of IGT, has to infer what IGT may look like from the alignment of text over several lines. Inevitably, such an inferencing approach results in many false positives and the data needs to be manually screened before it can be deemed to be a true sample of IGT. With the adoption of a standard IGT format such examples could be identified by web services and permit the retrieval of all and only IGT examples.

In the Heath example under discussion, we opted to use EOPAS[6] (Schroeter & Thieberger 2006) both because it is a proposed standard and because it is built to work with primary media (as discussed in the next section). EOPAS is designed to take files in formats commonly created in the course of analysis, for example Toolbox IGT with timecodes linking the text back to the primary media, which it then transcodes to its schema. It also transcodes the media to formats playable using HTML 5 and highlights the textual chunks as their timecode is reached. As each utterance in EOPAS is citable to the level of the morpheme we are

[2] including Bow et al. (2003), Hughes et al. (2003), Hellmuth et al. (2006), Schmidt (2003), Jacobson (2006), Jacobson et al. (2001), and Palmer & Erk (2007).

[3] http://typecraft.org

[4] http://www.galoes.org/

[5] http://odin.linguistlist.org/

[6] http://www.eopas.org/

able to link from external objects, in this case the grammar and dictionary, to and from the morphemic level of an EOPAS file, as can be seen in the online example.[7]

3.3 MEDIA In what could be considered an additional or fourth member of the 'Boasian trilogy' the audio or video recordings resulting from most fieldwork provide the basis for transcriptions and subsequent analysis. Maintaining the connection between the media and the derived or secondary materials (using Himmelmann's 2012 terms), as discussed earlier for the other outputs of language documentation, is now easily achieved and is slowly being taken up by linguists. A primary requirement of the citation of such media is that it have persistent identification which is provided by lodging the data in a suitable repository. Some repositories allow the media to be played directly from the archival location, while others allow for derived versions of archival material to be housed in accessible locations. EOPAS, discussed above, displays synchronised IGT and media and can either play from existing media files or from files uploaded to the EOPAS server. We included the media for a single text in our current project and encoded the IGT in a format suitable to allow for an EOPAS representation.

3.4 LEXICON There are a number of encoding formats for lexica which have been proposed or are in use (for a slightly dated summary, see Maxwell 2008). We have considered three[8] of these in developing this project: the Lexical Markup Framework (LMF[9]), the Open Language Interchange Format (OLIF[10]) and the Lexical Interchange Format (LIFT[11]).

Both LMF and OLIF have emerged from the environment of natural language processing and computational linguistics, and as a result both have rather Eurocentric models of the categories relevant to lexical data. In the case of LMF, this is perhaps less problematic as the data categories are kept separate from the specification of the format (Maxwell 2008:16). However, neither of these formats intuitively maps to the models of the lexicon used by descriptive linguists. Therefore we have preferred to use the Lexicon Interchange Format (LIFT) developed by SIL as our encoding scheme for the lexicon (Hosken 2006). This format is intended to provide a well-structured XMLversion of the type of lexicon commonly used by linguists working with the Toolbox software and its successor FLEX. These software tools are popular with descriptive linguists, and using an encoding which is close to their file formats has obvious advantages.[12] LIFT is also explicitly an *interchange* format and we expect that scripts will become available shortly to move lexical data between this format and other popular and well-supported formats, including LMF and OLIF.

Figure 3 shows an example of a LIFT encoded lexicon entry. Note that the `<example>` elements in this entry consist only of a reference to a source. This follows exactly Heath's practice in his dictionary. For our purposes, what is important is that the source information

[7] http://users.monash.edu.au/~smusgrav/Nunggubuyu/17.HTML

[8] We preferred these three options over the TEI dictionary format (http://www.tei-c.org/release/doc/tei-p5-doc/en/HTML/DI.HTML) mainly due to their being more targeted on small bilingual dictionaries.

[9] http://www.lexicalmarkupframework.org/

[10] http://www.olif.net/

[11] http://code.google.com/p/lift-standard/

[12] Heath's work on Nunngubuyu predates the availability of Shoebox (the precursor of Toolbox). The Nunngubuyu dictionary does exist in electronic form, as a Filemaker database.

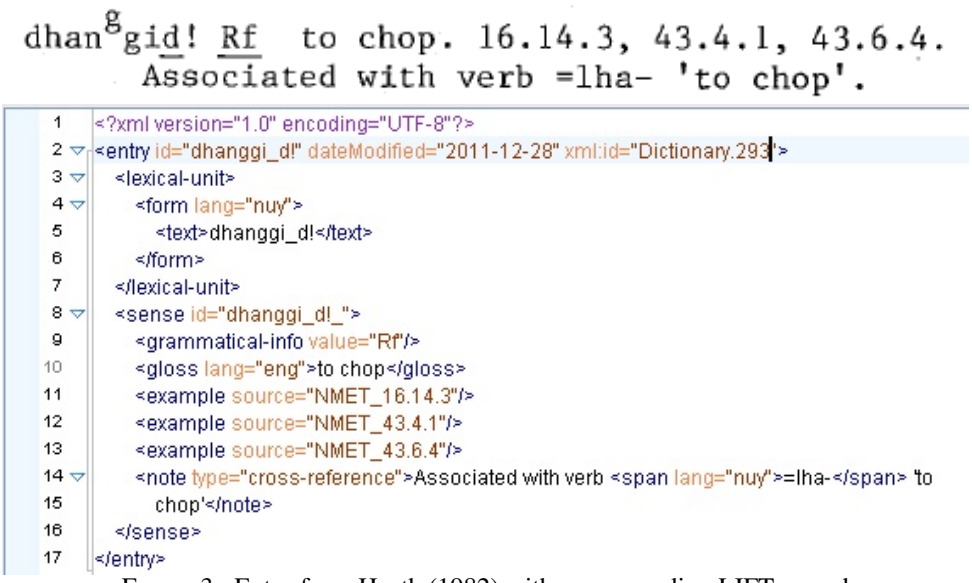

FIGURE 3.: Entry from Heath (1982) with corresponding LIFT record

stored as an attribute in that element can be accessed and parsed to create a hyperlink to the relevant section of text when the lexicon entry is transformed into an HTML page. The 'source' attribute is given here as a reference that can later be converted into a persistent identifier or URI, depending on the context in which the documents are delivered.

This entry also includes an identifier attribute in the `<entry>` element which is not a part of the LIFT format (`@xml:id`). This attribute is used for tracking references between the dictionary and other parts of the description; fuller discussion is presented in the following section. The numeric code is derived from the existing electronic version of the dictionary.

3.5 GRAMMAR We have already mentioned in section 1 that descriptive grammars have a more or less standard format. However, this format is a normative set of expectations about the order and means of presentation (see papers in Evans et al. (2006), and in Payne & Weber (2006)), rather than an accepted template, and it is therefore not surprising that no encoding for this document type exists. There are various kinds of encodings for grammars, including computationally tractable grammars (see also Thieberger (2009:376) on steps toward embedding a grammar in data), but we are here concerned with a marked-up textual encoding that permits interlinking. Our strategy in this example is to base our encoding on the Text Encoding Initiative Guidelines (TEI Consortium, no date) with additional elements as required.

The overall structure of the project requires that references from within the grammar to other parts of the description should be consistent in form and easily transformed to URLs which will point to relevant pages for online presentation. Heath's text already includes references to examples in the volume of texts and internal cross-references to other sections of the grammar. Although Heath does not include explicit links between the grammar and

the dictionary, we wish to allow for such links in our version of the description. Such links are certainly implicit where Heath discusses specific lexical items within the grammar, and making the linking explicit is of great value as the language has considerable morphophonemic complexity which can make tracing lexical forms difficult.

We encode all references with the TEI <ref> element. This allows for the text representing the reference to appear in the document, thereby preserving the appearance of the original source. The location of the endpoint of a link is stored in the @target attribute of the <ref> element and takes the form of a pointer to the part of the description which is the target (Grammar, Dictionary or Text) followed by a numerical code. In the case of the grammar proper, the code matches the division shown in the table of contents and sub-heads; for example, chapter 7 sub-section 20 is coded as <ref target="Grammar.7.20">. References to texts follow Heath's practice and specify the text identifier, a section number and a line number; for example a reference to line 2 of the third section of text 157 is encoded: <ref target="Text.157.3.2">. The line numbering is an artefact of the original document; we have not yet encoded a large enough sample of the text collection to know whether this information will actually be useable in the web presentation or whether the interlinear presentation described in Section 3.2 will rewrap texts in a way which makes this level of detail redundant. Retaining information from the source is of course best practice in this situation. References to the dictionary are to numerical codes which are an artefact of the existing electronic version of the material (FileMakerPro database); for example a reference to the lexical item *i:-jung* is encoded: <ref target="Dictionary.4720">.

In all cases, the target material has to be coded with an identifier which exactly matches the originating pointer. This is done with an @xml:id attribute included in the relevant element of the different types of material. This coding has already been illustrated with the lexical entry example in Figure 3; similar attributes are attached to the element which contains each section of the grammar and to the element <phrase> which holds each section of each text (and this can focus down to the level of <morpheme>). Figure 4 is a section of grammar text with all three types of reference illustrated: line 57 includes a reference to the dictionary (created in our encoding), line 61 includes internal references to other parts of the grammar, and lines 78ff include references to text examples.

One additional type of reference occurs in the grammar, that is, citations of other works. The online presentation has a bibliography page, and citations are therefore encoded as pointers to items on that page. For example, a reference to Hore (1978) [1979][13] is encoded as <ref target="Bibliography.Hore.1979">.

Figure 4 also shows that we make extensive use of the TEI <foreign> element to encode words and phrases which are not English. In fact, all the examples of this element in figure 4 enclose Nunggubuyu material, but in other places Heath includes cognate forms from other languages and the use of the @xml:language attribute is not redundant.

4 Further Development A small segment of the description of Nunggubuyu is available online at http://users.monash.edu.au/~smusgrav/Nunggubuyu. The XMLsource of these pages was hand-coded and HTML was then generated using search-and-replace in a text editor. Obviously, these procedures are time-consuming and, having established reasonably

[13] Heath 1984 lists this work as Hore 1979; however the date of issue for volume 17 of *Oceanic Linguistics* is 1978. Our internal reference retains Heath's error, but the Bibliography page includes a correction and clarification.

```
<p>The Prox forms show root //<foreign xml:language="nuy">i:-</foreign>//, which of
course becomes /<foreign xml:language="nuy">yi:-</foreign>/ word-initially by rule
P-5. Since Prox is generally /<foreign xml:language="nuy">ya:-</foreign>/, we could
say that the shift of //<foreign xml:language="nuy">a:</foreign>// to /<foreign
   xml:language="nuy">i:</foreign>/ is due to the following /<foreign
   xml:language="nuy">j</foreign>/ by V-Fronting P-50, a set of unproductive and
morphologically restricted shifts of this type. The complete Prox derivative is
normally /<foreign xml:language="nuy"><ref target="Dictionary.47.20">i:-jung</ref></foreign>/ or /<foreign
   xml:language="nuy">i:-jinyung</foreign>/, where the endings may be identified
formally as Absolute /<foreign xml:language="nuy">-yung</foreign>/ (<ref
   chapter="7" section="7" &#167;7.7</ref>) and relative case marker
   /<foreign xml:language="nuy">-yinyung</foreign>/ (<ref target="Grammar.4.30">&#167;4.30</ref>, cf. <ref target="Grammar.7.20">&#167;7.20</ref>), respectively. If so, we should set
the root up as //<foreign xml:language="nuy">i:G-</foreign>// with final stop
archiphoneme, so that //<foreign xml:language="nuy">y</foreign>// will become
   /<foreign xml:language="nuy">j</foreign>/ by Hardening P-18. (Prox /<foreign
   xml:language="nuy">ya:-</foreign>/ in regular DemPro forms cannot end in a stop,
cf. WARA class form /<foreign xml:language="nuy">ya:-wi</foreign>/.) As for the
Anaph derivative, we get /<foreign xml:language="nuy">bu-junyung</foreign>/, which
could possibly be set up as //<foreign xml:language="nuy">baG-yinyung</foreign>//
with double application of V-Assimilation P-37 from right to left (P-37 is another
collection of morphologically restricted changes of this variety). Obviously, these
forms are synchronically specialised and are best treated as separate lexical forms.
However, /<foreign xml:language="nuy">bu-junyung</foreign>/ does share with other
forms of Anaph /<foreign xml:language="nuy">ba-</foreign>/ the increment /<foreign
   xml:language="nuy">u</foreign>/ when preceded by a prefix, hence /<foreign
   xml:language="nuy">an-ubu-junyung</foreign>/.</p>
<p>Attestations of /<foreign xml:language="nuy">i:-jung</foreign>/ are these: simple
   /<foreign xml:language="nuy">yi:-jung</foreign>/ <ref target="Text.10.12.1"
      >10.12.1</ref>, <ref target="Text.36.1.2">36.1.2</ref>, <ref target="Text.143.16.1">143.16.1</ref>; MANA forms /<foreign xml:language="nuy"
      >man-i:-jung</foreign>/ <ref target="Text.157.3.2">157.3.2</ref>, <ref
      target="Text.157.5.6">157.5.6</ref> (both clearly refer to MANA nouns). A
variant /<foreign xml:language="nuy">yi:-jiny</foreign>/ is found <ref target="Text.43.3.3">43.3.3</ref> if the transcription is correct.</p>
```

FIGURE 4.: Section of encoded grammar (from Heath 1984, section 7.25)

stable principles for encoding the material, our next priority is to automate the process as much as possible.

A first step in this endeavour will be to attempt to produce electronic versions of the original texts using optical character recognition software (OCR). As discussed in Section 3.1, Heath's texts use an idiosyncratic orthography with superscript characters which are important. The original text also uses subscript characters in gloss lines to indicate various grammatical properties. All of these characters will need to be captured by OCR if the process is to be useful. Even if OCR is successful at that level, it will still be necessary to use scripts to insert some appropriate encoding of the non-standard characters. It seems quite likely that the post-editing which will be needed to make an OCR version of the material useable may be so extensive as to render the whole process too slow. The alternative then would be to have the source materials retyped directly to our preferred encodings; this would also be time-consuming (and expensive), but may be a more efficient alternative. If OCR turns out to be a viable means of generating a complete electronic version of the material, we would still need to develop scripts to add encoding to the basic text. This is still not a particularly attractive option as such scripts will be specific to the source with which we are working. If in the future we wished to import another pre-existing description to our format, we would almost certainly need to at least considerably modify the scripts used to add mark-up.

Various issues concerning the internal linking of the materials will arise when we are able to work with the entire description. As noted in Section 3.4, we believe that it will be useful to include links explicitly which Heath left as implicit, such as those pointing at rules (such as P-5, P-50 etc. in Figure 4) or between lexical forms in the grammar and corresponding dictionary entries and those between dictionary entries which are cross-referenced. Three questions will have to be addressed in generating such links. First, to what extent is it useful to make the implicit structure explicit? There are cases where doing so is clearly advantageous; in the following paragraph we discuss an instance where we have included a reverse link (from text to grammar) to complement the link Heath made between grammar and textual instance. But we can imagine that in some cases fully explicit linking might be counterproductive: will the user always want to have access to every textual instance of a common morpheme? It will be desirable to allow the possibility that a user can search for every instance, but listing every one with an explicit link would probably be unnecessary (See Good's (this volume, section 8.1) distinction between examples and exemplars—the latter being carefully selected to illustrate a point, while the former are more or less the harvested results of a search). Second, how can this process be done automatically? This is only a problem for dictionary entries as references to texts and to sections of the grammar will always be in a form (numerical code) which can be parsed automatically. For the dictionary, however, we believe that it will be necessary to create a look-up table against which the texts and grammar can be compared to identify forms which should be linked to dictionary entries. The third question to be considered is whether the resulting structure should be implemented as simple hypertext links, or whether it will be more stable and efficient to use a link table (that is, a simple database) to store the links. Doing so will mean using some scripting language to actually implement the links, and this is not desirable; in principle, we would prefer to keep the whole implementation in HTML

only. However, there are additional considerations, to which we now turn, which suggest that such an HTML only implementation will not be practical.

Even in the very small sample which we have produced so far, we have encountered a problem in realising the complexity of the links which allow the user to move from one part of the description to another. In the text sample online, we have linked some forms to their dictionary entries; this has been implemented at the morphemic level of the text. But there is one case (*da:n* in line 1 of the text) where we have also implemented a link from this morpheme to a section of the grammar. This is a link which is only implied by Heath: the grammar refers to the text as a relevant example, but there is no annotation in the text to indicate the relevance of the grammar section. There are thus two targets linked from a single source morpheme at this point. We have dealt with this by instantiating the link to the dictionary on the morphemic analysis line and the link to the grammar on the text line, and this is an adequate solution in this case. However, we are aware that there will certainly be cases where a single form in a text will need to be linked to more than two targets. For example, a motion verb form might be linked to a description of the class of verbs to which it belongs, to an analysis of the morphophonemic changes which the form undergoes as well as to a discussion of how directionality is treated in the language. With a link to the dictionary as well, this will require four links to be instantiated from only two source forms, which is not possible using HTML only. We suspect that we will want to use a technique such as menus which pop-up when the cursor is over a form in order to handle this sort of complexity. We also suspect that, when the full complex structure of links is created, the actual appearance of texts on the screen will be problematic. Every form, or almost every form, will be the source of a link. If these links are simple HTML links, then (almost) every form will be a link, making it difficult to visually distinguish links from non-links in the text. This is problem that we expect to be able to deal with using style-sheets in the delivery version. If we need to use some programming resources to handle multiple links from a single source, then it will probably be worth also using such resources to implement links to the dictionary with keystrokes. For example, selecting a form on the morphemic tier and using the keys `Alt+D` would take the user to the relevant dictionary entry in every case. We also anticipate that there will be problems to solve for links to grammar sections which discuss constructions rather than individual forms. It is not immediately clear whether the source of such links should be individual words or morphemes, or the entire span of text which is relevant.

The various questions just raised will become relevant when we have all of the description encoded and potentially available as hypertext. At that point, we expect to have to make decisions about how to deal with the problems and this will most likely mean making a decision about a programming or scripting language to use to develop the online environment which we want.

A further and critical matter to be confronted in the creation of any data is the longevity of the material created. As stated earlier, one motivation for encoding a grammatical description is explicitly to allow the rich set of links implicit in a grammar to be stated and stored as text, a preferred archival format. Persistence of the primary media and any secondary analysis would, as a matter of course, be provided by an appropriate repository and the links between objects described here would resolve to these archival forms or derived versions (as HTML, or streaming media for example) in suitable locations. Although we have

introduced the possibility that delivery in a browser will require resources beyond those offered by (current versions of) HTML, our approach ensures that the linking structure is explicitly encoded in archival data sources. Optimal presentation may depend on particular implementations, but presentation is independent of the basic data. We note that in the case where the data is not derived from printed material, this means that a rendering as a printed object will also be easily achieved.

5 Designing Electronic Grammaticography Electronic grammaticography is the topic of all chapters in the present volume, and also of Good (2004), Nordhoff (2008), and Bender et al. (2004). Our project is offered as an example both of retrofitting an existing grammatical description and of setting out what requirements more elaborated grammar-template projects could include. We have described here the preliminary stages of a project which aims to make a classic grammatical description available as an electronic resource. We have discussed a number of problems which arise in transferring such material from its original form as printed text to a new format which makes new and richer possibilities available, and the reader might be tempted to ask whether there is any point to grappling with such problems; might it not be simpler to work with newly-produced materials which are already available in electronic formats? Obviously, we believe that the effort is worthwhile, and we would like to close by offering some of our reasons for this view and showing how they relate to basic issues in the development of electronic grammaticography.

First, most of the problems we have discussed in Section 3 are about choosing suitable formats and encodings for source material. Most of these problems would still need to be faced in working with recent materials. Many linguists work with texts and lexicon in Toolbox, but this practice is not universal, and even those who do structure their files differently. Even for material originating in Toolbox, decisions would need to be made about a common encoding to be used as an interchange on the way to online presentation, and such an encoding would also have to be used for materials from other source software. Although the practical problems of transferring material from one format to another would be simpler for description born digital, the conceptual issues would be the same. And for actual grammatical description, the range of formats used by different scholars would be considerable; again the conceptual issues are the same as those we have discussed. (If we are able to present grammatical description online in a useful and attractive way, we would hope that other scholars might then adopt our encoding practices, but we are not aiming to impose a standard on our colleagues, only to find a pragmatic solution.)

Second, we believe that it is important to be able to handle grammatical description which already exists as legacy materials. The advantages which we see for the mode of presentation discussed in Section 1 are considerable. Assuming that we can achieve the aims which we have set out here, we believe that it will be very desirable to make as broad a range of grammatical materials as possible available in this way.

Third, and following from this previous point, we believe that the design of electronic grammaticography should incorporate the best practice of traditional grammaticography and then extend it. Heath's work is an ideal starting point for this endeavour. As we discussed, Heath had a carefully considered view of how the parts of his description should interact for the user. The format which was available to him made this very difficult in practice but we can now attempt to implement that interactivity in a more congenial format.

Even replicating what Heath included in his work means addressing fundamental questions about how electronic grammaticography can work. Going beyond Heath and making the web of interconnections more complete and more explicit poses additional problems. We suggest that adequate solutions to these problems will provide a sound basis for one version of electronic grammaticography.

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Reference grammars for speakers of minority languages

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Most of the work done in grammaticography focuses on the writing of grammars for an audience of linguists, and more specifically, typologists. In this paper, we present a grammaticographic model designed mainly to take into account the needs of minority language speakers, because they play a central role in the preservation of their language. However, since in minority language situations it is not possible to generate as many grammars as there are different potential end users, we propose a multilevel grammar, based on our experience as grammarian of Innu, a First Nation language spoken in Quebec (Canada). In this type of grammatical description, the first (main) level is addressed to non-specialist users, the speakers of the language being described, whereas grammatical material aimed at other users (such as linguists) is presented in secondary levels and is limited to core information. Our grammaticographic model was initially conceived for paper (printed) grammars, but we believe that electronic publication offers interesting solutions for multilevel grammars, while paper (printed) grammatical descriptions have greater limitations.

1 Introduction Grammaticography as a new branch of linguistics was developed almost at the same time as documentary linguistics (Gippert et al. 2006).[1] The development of these new domains of linguistics in the recent past is not a coincidence. In fact, there is a link between both domains, since the development of a grammar is theoretically part of a documentation program for endangered languages. Furthermore, these fields of research were proposed as solutions, among others, in preventing language extinction. But, without denying merit to those who drew up the basics of grammaticography, we believe it maintains an important weakness: most of the work done in grammaticography, i.e. the business of writing grammars, aims the grammatical descriptions primarily at linguists, usually ignoring the minority language speakers, who have their own specific needs. However, we believe that the speakers of an endangered language play a central role in documenting their language, even though they are not specialized in linguistics. Therefore, in our PhD thesis

[1] Thanks to Sebastian Nordhoff and to an anonymous reviewer for their comments on an earlier version of this paper, and thanks to Robert Papen not only for his comments, but especially for the revision of the English text.

(Baraby 2011a), we propose a model of grammaticography which takes into account speakers' needs. More precisely, from our experience as a grammarian of Innu, an indigenous language spoken in northern Quebec, we have developed a set of principles which may help in constructing a model of a reference grammar intended particularly for Innu speakers.

Developing a reference grammar for a minority language, often under-documented, usually unwritten, and probably endangered, is quite different from writing a grammar for languages of wider communication such as the main Indo-European languages. In the latter case, it is possible to generate as many grammars as there are different theoretical approaches, different end users, and different objectives. This situation is highly unlikely for most minority languages, where it is generally impossible to develop such a multiplicity of different grammars. In short, writing a grammar for a minority language raises the following question: is it possible to develop a reference grammar aimed at both types of audiences, linguists and non-specialized users?

Actually, writing grammars for non-specialized speakers brings its own challenging issues, which are different, in many regards, from grammaticography conceived for linguists. In the following sections, we will deal mostly with the question of the end users of a particular grammar and the solutions we propose in achieving the task of documenting a language mainly for the speakers of that language, but also for any other interested public, such as linguists who want to learn something about the inner workings of the language. Among the means we propose for such a grammar, based on our experience in the Innu language grammar project, is a multilevel grammar, which we believe can be achieved both in printed and electronic versions. Would an electronic grammar be a better medium for the model of grammar we are proposing? At first glance, it may seem so. However, we do not see the two media types as being opposed, but as complementary options. In our view, developing a grammar on Internet may pose specific challenges, but it also shares problems with writing a grammar for a printed book version.

2 The problem Developing a grammaticography for users without specialized training in linguistics raises a number of issues, including the selection of the eventual end users and specific objectives.[2] Among others, these issues concern different choices regarding the theoretical approach, the language used in writing the grammar itself, including the grammatical terminology and metalanguage, and the depth of the grammatical description envisaged. Furthermore, there are questions referring to the content itself, for instance which phenomena to describe, the scope of the description, the organization of the content, etc. And finally, the issue of the type of grammar planned is also often raised as to whether it is to be a pedagogical grammar or a reference grammar. Since we believe that the choice of who the eventual end users are to be determines all the other choices made by the grammarian, the following discussion mainly concentrates on this particular issue.

In our grammatical model, we place the speakers of the language being described in the foreground. But making this basic choice is not as easy as it appears because, as previously stated, in the case of minority languages, the possibility of being able to produce more than one reference grammar is very low to non-existent. Therefore, even if we choose to produce

[2] In our thesis, we also discuss the following issues: possible types of grammar, language register, comparison with other languages (related or not), language variation and linguistic norms, description of an oral and/or written language, use of the orthography (if there is one), use of parts of speech, presentation of examples.

a grammar mainly for speakers who are not specialized in linguistics, we are aware that it is also important to document the language for other users, including linguists, but only as secondary end users. However, such a decision, which takes into account the needs of different types of users for the same product, raises a big problem: *Is it possible to write a reference grammar for different users having different expectations*? This is a complex issue in a grammaticography mainly developed with the objective of documenting minority languages. Indeed, aiming at heterogeneous users could bring about dissatisfaction with the content of the grammar on the part of all users.

As a solution to this problem, we propose a multilevel grammar, where most of the content is addressed to a non-specialized audience, speakers of the described language (it constitutes the *first* or *main level*), but with some additional grammatical information (the *secondary level*) aimed at specialists, such as linguists. More details about this type of reference grammar are given in Section 4.

Once the end users and the objectives of the reference grammar have been established, the grammarian must decide if the grammatical product is to be a printed book or an electronic document. Both media have advantages and inconveniences. In our thesis, we primarily discuss solutions to produce a good grammar for Innu speakers, with secondary attention paid to a specialized audience.[3] Here, we also intend to look at possibilities of electronic grammars, especially for the kind of multilevel grammar we are proposing for non-specialist end users. Is an electronic edition a better choice for such a grammar? It certainly offers good resources to produce the kind of multilevel grammar we are envisaging. However, since electronic tools are not available everywhere, and also because some users are not yet ready to use these tools, we believe that printed grammars will be maintained, according to users' needs or wishes. And even where electronic tools are available, both grammars can be seen as complementary ways to reach the main objective: documenting an underdescribed language, and giving speakers a tool to develop a good formal knowledge of their language.

3 The Innu People and their language Before discussing our grammaticographic model further, below we give a short description of Innu[4] communities and their language, because we think their linguistic situation may be comparable to many other minority linguistic groups, and above all, because it is their linguistic situation that convinced us to work on a reference grammar of their language. Even if we are well aware that all sociolinguistic situations are not identical, we believe that the grammaticographic principles and solutions we are proposing may be useful elsewhere.

3.1 The linguistic, geographic, and demographic situation of the Innu communities Innu is part of the Algonquian language family and is spoken in Quebec and Labrador. It is closely related to Eastern Cree, also spoken in Quebec, and to Naskapi, spoken in Labrador. The Innu live in ten isolated villages spread out over the immense northern terri-

[3] As specialised audience, we think of linguists working in typology, Algonquian linguistics, historical linguistics, anthropological linguistics, etc.

[4] The Innu were previously called Montagnais by French speakers. They always called themselves Innu ('human being', now 'Amerindian' and 'Innu First Nation') and it is this term that is now officially used not only by the Innu organizations, but also by federal (Canadian) and provincial governments, and in the media.

tory of Quebec and Labrador, Canada. Some of these communities still cannot be reached by road. Around 10,000 people use Innu as a first and every-day language. The rate of retention of the language varies from one community to another: extinct in one, spoken by one third of the population in another, majority language of nearly 75 % to 95 % of the population elsewhere. The Innu language therefore is still very vigorous in a majority of Innu communities, where it is the first language learned by children and is used at home and in the community at large. Except for two communities (Mashteuiatsh and Essipit), Innu is also used in religious ceremonies, local administration, community radio, and, with the intervention of interpreters, in health, social and legal services.

Nevertheless, pressures from the dominant language are very strong, since virtually all Innu are bilingual today, with French as their second language in most Quebec communities, and English in the Labrador community (and partly in Pakuashipu, Quebec). If Innu is not considered endangered enough to disappear in the short term, its survival is not guaranteed in the long term, because of the relatively low number of speakers.

The Innu language constitutes a continuum of dialects, geographically spread out from the most western one, Mashteuiatsh (Lac Saint-Jean), the "central" dialects, with Pessamit, Uashat-Maliotenam on the upper north shore of the Saint Lawrence and Matimekush (Schefferville, Northern Quebec), and Mamit (on the lower north shore of the Saint Lawrence), as well as Ekuantshit, Natashquan, Unamen-Shipu, Pakua-shipu; the dialect of Sheshatshiu (Labrador) is somewhere between the central and Mamit dialects. These dialects are quite different, morphologically or phonologically speaking, but speakers of different dialects still readily understand each other.

Much as for most Amerindian languages, Innu was until lately an oral tradition language, but a standardized writing system has been developed, except for Mashteuiatsh (Lac Saint-Jean, Quebec).[5] However, this standard orthography is not necessarily mastered by all speakers, who more often turn to French (or English) for their written communications. In fact, oral and writing habits are diglossic: Innu for oral communication within the community, French elsewhere.[6]

3.2 The Innu language in schools Locally, Band councils run all Innu schools, from kindergarten to high school. More and more Innu teachers are teaching in these schools, however most of these certified teachers are not involved in Innu language teaching: they teach the various subject matters determined by the regular provincial programs, using French or English in the classroom. In fact, these teachers prefer to teach these subjects since they are properly supported with well designed curricula and pedagogical material.

If Innu is indeed part of the school curriculum, usually taught once or twice a week (1 or 2 hours/week), the working languages of the school, including the languages in which academic subjects are taught, are French in Quebec and English in Labrador. Also, except for help from the *Institut Tshakapesh* (see below), Innu language teachers, all competent speakers, but without adequate training in linguistics, Innu grammar, or even language teaching

[5] Because the Mashteuiatsh dialect is different from other dialects (it is more conservative) and it is learned by children as a second language, the community did not adopt the standardized orthography. We are now working with the community to develop their standard writing.

[6] To know more about the development of a standard orthography and the role of writing in Innu communities, see Baraby (2000, 2002, 2011b).

pedagogy, are often left quite isolated in their specific teaching tasks. In fact, teaching Innu is not perceived as being as attractive as teaching regular subject matters. Nevertheless, in spite of all these difficulties, the Innu language teachers are highly motivated in transmitting their language, and in learning more about it.

Fortunately, a university program for the teaching of Innu has recently been developed. Also, tailor-made courses in linguistics for Innu teachers are now offered two or three times a year,[7] as well as workshops on language teaching. The *Institut Tshakapesh*[8] (a cultural and educational institute for the Innu people, based in Sept-Îles, Quebec) has taken leadership to promote Innu language preservation and development. The institute supports Innu teachers in different ways, including the organization of meetings, workshops and courses, funding the production of curricula, pedagogical materials, reference materials, hiring specialists in linguistics or in language pedagogy, etc. Except for the two communities mentioned above,[9] where the language is not spoken by children, Innu is taught as a first language to students who are already fluent in it. The students are expected to improve their oral skills and acquire literacy in Innu. Since the traditional way of life has changed a lot, language transmission has also changed. Parts of traditional vocabulary are being lost, and the language of the youth now includes more and more loanwords, systematic code switching and code mixing (with French and more rarely English). At this point in time, we do not know if pressures from the linguistic environment have already altered certain grammatical structures of Innu, but it is quite possible. Thus, Innu language courses in the school curriculum have an important role to play in preventing language erosion or loss, as do the families and communities themselves.

3.3 Documentation of Innu Innu is probably one of the most documented languages of all of the native languages of Canada, but except for dictionaries published since the 70s, the majority of linguistic descriptions was intended for linguists and published in academic journals. At present, there exists no comprehensive reference grammar for Innu, but we are now working on such a grammar, specifically aimed at Innu speakers (Baraby & Drapeau, forthcoming). A conjugational guide (Baraby 2004) is however available, and some electronic learning material is also presently being developed.[10]

The completion of a reference grammar will answer a pressing request which comes from the Innu themselves, particularly from Innu language teachers. This reference work is necessary to help Innu speakers develop metalinguistic knowledge about their language. As well, it will be a good tool in supporting the development of pedagogical material and literacy.

In sum, producing a good Innu reference grammar, accessible to non-specialists, will give a good opportunity for linguists to transmit to non-specialized speakers the grammatical

[7] The Université du Québec à Chicoutimi is providing two undergraduate certificates (10 courses each) specially designed for First Nations : *Technolinguistique autochtone*, *Transmission d'une langue autochtone*.

[8] http://www.icem.ca/icem/

[9] In these two communities (Mashteuiatsh and Essipit), Innu is taught as a second language.

[10] Marie-Odile Junker, a linguist from Carleton University (Ottawa) and specialist of Eastern Cree, has developed electronic material for the Cree in Quebec (urlhttp://www.eastcree.org/textstyleInternetlinkwww.eastcree.org), and she is now collaborating with the Institut Tshakapesh to elaborate similar kinds of material for Innu, mostly for pedagogical use.

knowledge they have acquired over time. We believe it is an interesting way of assuring that specialized knowledge does not remain ensconced in academia, but returns to the most prominent actors in the maintenance of an endangered language, the speakers themselves.

We sometimes hear linguists say that minority languages speakers are not really interested in having a (written) grammar of their language. We understand that this is not a priority everywhere. However, the facts from the Innu language situation demonstrate quite the opposite: many Innu speakers are highly motivated to learn more about the grammar of their language, as long as they are given a reasonably easy access to it.

4 A GRAMMATICOGRAPHY INTENDED FOR MINORITY LANGUAGE SPEAKERS Our work on Innu grammar has raised a number of issues that led us to develop a grammaticographic model, conceived for non-specialists, i.e. the speakers of the language being described. Besides the targeted end users which we discuss in the next section (4.1), the main characteristics of this model are the following:

- The grammar is a *reference grammar* rather than a *pedagogical* grammar. This follows from the fact that the main objective is to document the language in a comprehensive way.[11]
- French is used to write the grammar as well as for the metalanguage and grammatical terminology, because the Innu are familiar with French from their schooling. Actually, they are more used to read in French than in Innu. Moreover, writing the grammar in a relatively well-known language such as French allows most users who are not speakers of Innu to read the grammar, including linguists or other interested users (see Section 4.3).
- The writing style is rather formal, but with a simple and precise vocabulary.
- Comparisons with French, English and other Algonquian languages are made, whenever they help users transfer their metalinguistic knowledge from one language to the other, for instance, from school knowledge (French grammar) to mother tongue. It is also interesting for Innu speakers to see the links between their language and other related languages such as Cree, Naskapi or other Algonquian languages.
- Whenever possible, the grammatical terminology used to describe the language is the one used in traditional French grammars, because it is already familiar to most Innu speakers. However, terminology may also be innovative, in order to fill terminological gaps in traditional French grammar. Even if some typical Algonquian linguistic ter-

[11] Pedagogical grammars are usually less comprehensive than reference grammars. The former usually have as objective the learning of a language as a foreign or second language, or the learning of writing rules based on grammatical structures. The organization (or progression) is also different in both types of grammar. Pedagogical grammars usually include exercises, while reference grammars do not. But the boundaries between both types are sometimes loose, since both types may have pedagogical purposes. In fact, the different types of grammatical descriptions are on a continuum, and a reference grammar for non-specialists is closer to pedagogical grammars than is a grammatical description specifically intended for linguists (see Germain & Séguin (1995:46-56), Dirven (1990:1-2), Baraby (2011a:210-236) for further details).

minology is used, it is sometimes abandoned in light of the current knowledge of the language and in order to meet the particular needs of non-specialist users.[12]

- Innu is an oral tradition language, so the grammatical description focuses on this aspect, but it also takes into account standard orthography. For instance, examples are given in this orthography, instead of being transcribed in a phonetic alphabet. Phonetic transcriptions are minimally used, mostly in sections specifically addressed to linguists.
- Dialect variation is considered, but only to a certain point. The use of a standardized orthography is a good solution in giving a more synthetic description that is accepted by all speakers.[13]
- Even if the language spoken by elders is generally seen as the norm, i.e. "good Innu language", the speech patterns of all generations are considered in the grammatical description.
- The general organization of the content is "bottom up", starting with the simpler notions, for instance the word before the sentence, the noun before the verb, etc. It goes from structures to functions or from functions to structures.
- The theoretical approach is a "traditional" one, close to traditional French grammar, with additions to reflect particularities of Innu grammar; the latter being based on recent research by Lynn Drapeau, co-author of the grammar and specialist of Innu linguistics. In fact, this comes close to what Dixon (1997, 2010) proposes in his *Basic linguistic theory*: to describe languages in the perspective of language documentation.

Obviously, each of these characteristics could be discussed in more detail, but we will now focus on the issue of multiple end users for a grammatical description and the solution we propose to achieve this objective, a multilevel grammar.

4.1 Targeted end users for a minority language reference grammar The status of the main readership of a grammar, i.e. the targeted end users, needs clarification, because each type of grammar user is in fact not homogeneous, some being laymen, other being linguists. Basically, we distinguish two main target groups: non-specialists, for instance language teachers (the primary group); and specialists, for instance linguists (the secondary group). Each of these two broad groups may be heterogeneous.

Principal end user : language teachers As Mithun (2006:282) points out, non-specialized users are not all the same, depending on specific linguistic situations. Actually, a layman readership may include anyone interested in knowing more about the described language: speakers or non-speakers, teachers or students, advanced learners or beginners,

[12] For pedagogical reasons, we may decide to abandon terms whose meanings are opaque to laymen. For instance, in Innu there is a mode with a counterfactual meaning, but the term '*contrefactuel*' (counterfactual) is not well understood by Innu speakers. Also, other terms create confusion, for instance, *subjonctif* (subjunctive) and *subjectif* (subjective); in this case, we replace the latter with another term, *perceptif* (perceptive).

[13] The Innu orthography is not based on one particular dialect, but on principles such as the following : the Eastern (Mamit) dialect serves as a reference for grammatical spelling, while, when variations are more phonological, the Western dialect become the reference. In sum, speakers from all communities have had to compromise in arriving at an agreement on a common spelling system (Baraby 2000, 2004).

first or second language learners, having basic, intermediate or advanced knowledge in the grammar or even none at all, literate in the language or not, etc. For Mithun, it is also important to think about the future needs of the members a language community: those who are not interested in or able to use the grammar at present could become users later on, for instance, after some training.

For the grammar of Innu, we propose, as *main end user*, those speakers who have some basics in grammar, if not in Innu grammar, at least in school grammar, that is in French grammar,[14] for Quebec Innu speakers. More precisely, we choose Innu language teachers as targeted end users, for various reasons. First, because they are competent speakers of the language. Secondly, because they have had some grammatical basics in their language of schooling (French) and they also have a university degree in teaching, or they have had some training in pedagogy or in Innu grammar.[15] Finally and above all, because they are very motivated to learn more about the language they have to transmit to their students. Some of them, but not all, have had some basic training in Innu linguistics.[16] As main end users, we would also add any other professionals involved in different areas related to the Innu language: language curriculum designers and developers of pedagogical material, translators, authors and writers.

In our grammaticographic model, we claim that minority languages require reference grammars rather than pedagogical grammars, in order for them to be well documented, and in a comprehensive way, and such a grammar is probably not for beginners, users without any skill in formal grammar. In other words, in the reference grammar model we propose, the level of difficulty is *intermediate*, which means that main users are not specialists, such as linguists, but they have basic grammatical knowledge, if not in their first language, then in their second language. Of course, as mentioned above, this intermediate level may include other users than teachers such as language professionals, and, even advanced learners or any other person with basic grammatical competence.

Secondary end users Linguists will also get something out of the kind of grammar we are proposing; either a starting point to their curiosity about the language, or an overall view of it, which could be completed with more specialized publications. For instance, Innu has been the subject of many academic publications in linguistics, but even specialists may find it useful to get all the information in a single place, instead of having to search for information scattered in different journals and books. Therefore, obtaining grammatical knowledge about a minority language in one single document, that is in a reference grammar for non-

[14] The complexity of written French grammar makes possible some transfer of grammatical knowledge from French to Innu; for instance, agreement rules or the complexity of verbal inflections. Since most Innu speakers learn French grammar in school, we want to take advantage of this fact. Of course, this advantage does not hold for those who have been schooled in English, as English grammar (at least morphologically speaking) is not as complex as French grammar.

[15] The older Innu teachers may not have a university degree, but they have taken a certain amount of tailor-made courses over the years. We hope that younger teachers will graduate in education, since the expectations from school administrators are getting higher for their teachers.

[16] University Certificate programs in Amerindian language teaching and in "technolinguistics" (*technolinguistique*), designed by the University of Québec at Chicoutimi, are now available. Innu teachers may enrol in these programs, and one or two courses are available every year.

specialized speakers, is a good way of documenting a language, as much for linguists as for non-specialist speakers.

We now raise an important issue: Is the objective of documenting a language – meaning that the grammar has to be as comprehensive or complete as possible – compatible with the aim of producing a user-friendly grammatical description? On the one hand, comprehensiveness implies adding more complex information (usually addressed to linguists), such as information that may be necessary for better comprehension of the structure of the language and to the eventual development of linguistic typology. On the other hand, integrating this kind of material may be confusing to non-specialized users, especially if it is inserted in the main part of the description, that is, if it is included in the main grammatical text.

Considering the needs of different potential users in one single reference grammar may seem conflicting, especially with end users as different as non-specialized speakers and linguists. To achieve our objective of an accessible grammar, designed as much to document a language than to train and inform native speakers of it, we propose a document having more than one level (or layer) of reading, the main (first-level) text being user-friendly, with more specialized or complex information intended for linguists being presented at another level. In the next section, we will outline what we mean by a multilevel grammar.

4.2 A MULTILEVEL REFERENCE GRAMMAR Is it possible to write a reference grammar for different users, with divergent expectations? For under-described languages, the choice is limited, since it would be utopian to expect different kinds of grammatical descriptions for each potential audience. As a solution to this issue, we propose our multilevel (or multilayered grammar), that is with each level being aimed at a specific audience.

FIRST LEVEL: MAIN LEVEL The first level, intended for specific users, speakers of the language but without specialized training in linguistics or in grammar, is the main level. This means that these end users have priority over all others, and that most of the grammatical content (explanations and descriptions) is found at this level. For that matter, this level is mostly visually unmarked, and this is possible in printed as well as in electronic grammars. It includes the essentials of the language structures and functions, in other words, what the speaker needs to know about his or her language. Besides descriptions and explanations, there must be lots of examples. These have two purposes: to support the description given and to document the language. Also, tables, diagrams and figures are useful. Moreover, it is very important to give good, clear definitions of grammatical notions and of the terminology used to describe the language. Since describing a language implies the use of some metalanguage, readers of the grammar must become familiar with it. However this also means the metalanguage must be well defined and described. Again, the Innu experience has shown us that speakers can deal with grammatical metalinguistic terms, once they understand what they refer to in their own language.

Another point to stress is the question of the layout of a grammar for a non-specialized audience. Even if the visual aspect of the grammar may not be as important as the text itself, it is central to this kind of work since it is aimed at users who are not necessarily familiar with grammatical descriptions. In this case, the grammatical product must be attractive, using different typographical means such as different colors, fonts, the use of framed texts, etc. In a way, a reference grammar intended for laymen may resemble a pedagogical gram-

mar in its presentation, the objective being to help the user to easily find what he or she is looking for, providing the reader with certain types of information such as indexes, tables, etc.[17] Even in a printed grammar, it is possible to provide second-level information, clearly distinct from the first-level text, in using typographical treatment, such as different fonts or font sizes, frames, screens, etc. Otherwise, the non-specialist user may feel overwhelmed and be discouraged in going on. In fact, without being a pedagogical grammar, a minority language reference grammar has pedagogical aims, and this is true even for majority language grammars.[18]

In the introduction to his grammar of Ojibwa (*nishnaabemwin*), Valentine (2001: xxxi) mentions: "One reviewer pointed out that this grammar is actually a compound work, consisting of an introduction to linguistics as well as a grammar". Valentine explains his choice: "This I have done, again, to accommodate *my intended primary audience*, *those interested in teaching the language*, who typically lack extensive linguistic training". But the problem with Valentine's grammar is that all information is given in the same way, i.e. put on the same layer or level, the result being very dense text. This may very well discourage non-specialized users. Valentine (2001) is a good grammar, but it is not very user-friendly. Valentine probably wanted to document Ojibwa in a comprehensive way, and that is a legitimate objective we share; however comprehensiveness sometimes goes against the readability of the whole. To prevent this pitfall, we propose separating grammatical information on distinct levels (Drude this volume). On the one hand, we propose different levels intended for different users, as discussed above. On the other hand, we suggest another type of hierarchical organization, even at the first level. For instance, we present definitions or important remarks, often fundamental information, in box frames instead of in plain text, as in example (1).[19]

[17] Indexes, tables of content and cross referencing are some of the tools to help find information in a grammar, but this is true for any kind of grammar, aimed at specialists or not.

[18] In a recent meeting with colleagues about choosing a good reference grammar for French courses at the university level, an excellent French reference grammar was rejected, because its presentation was not judged user-friendly enough.

[19] Layouts of the examples we present here are not definitive, but indicative. Later on, we would like to work with a book designer, to find the best ways to format the book. In the meantime, we use simple word processing, to prioritize the grammatical information, the levels and the sublevels. The final product will have a better appearance than what we show here, and the distinction between each kind of rubric will be more salient.

(1) Examples of definitions of linguistic notions in Innu grammar, at *Level 1*

> **MODALITÉS**: Ensemble de faits linguistiques qui traduisent l'attitude du locuteur par rapport à ce qu'il dit; les modalités peuvent prendre la forme de modes (conjugaisons), de types de phrases (phrases affirmatives, interrogatives, de commandements), d'adverbes ou d'autres auxiliaires modaux, selon les langues. En Innu, on a surtout recours aux modes (suffixes modaux), mais également aux préverbes modaux et aux adverbes.
> En Innu, les informations véhiculées par les modalités portent, entre autres, sur le degré de certitude, de fiabilité ou de subjectivité de ce qui est énoncé ou encore sur la possibilité ou non de réalisation de l'événement dont il est question[20]

(source: Baraby et Drapeau, forthcoming, chapter on modes and modalities)

The definition in (1) may seem somewhat complex, especially for non-linguists, but it occurs after a number of "easier" chapters. For instance, Chapter 2 presents elementary concepts. (2) is an example of this kind of basic definitions and (3) is an example of basic remarks that may accompany plain text or definitions:

(2) Examples of definitions of linguistic notions or remarks in Innu grammar, *Level 1*

> Le VERBE constitue généralement le cœur de la phrase. C'est un mot qui sert à exprimer une *action* accomplie ou subie par le *sujet*; ou encore qui sert à décrire un sujet, un état ou un événement.
> Le *verbe* Innu varie en *genre*, en *nombre*, en *personne* et en *obviation*, comme le *nom.* Plus particulièrement, il varie aussi en *temps*, en *mode* et en *ordre*, formant ainsi des *conjugaisons*.[21]

(source: Baraby et Drapeau, forthcoming, chapter on basic notions, section *Les verbes*)

(3) Examples of fundamental remarks in Innu grammar, *Level 1*

> REMARQUE
> Du point de vue de la syntaxe, le verbe s'**accorde** habituellement **avec un sujet**, et parfois également **avec un complément**. Cet accord en *genre*, en *nombre*, en *personne* et en *obviation* est indiqué par des marques grammaticales ajoutées au verbe. De plus, le verbe peut varier de façon à indiquer le *temps* de l'action ou de l'événement décrit, ainsi que la *modalité* (jugement que le locuteur porte sur son énoncé). [22]

[20] Translation: *Modality : Linguistic facts that express the attitude of the speaker towards what he is saying; modalities may take the form of modes (conjugations), clause types (affirmative, interrogative, imperative), adverbs or other modal auxiliaries, according to the specific language. In Innu, recourse is typically to modals (modal suffixes), but also to modal preverbs and to adverbs.*

[21] Translation: *The VERB generally constitutes the very heart of the sentence (or clause). It is a word used to express an action accomplished by the subject, or which serves to describe a subject, a state or an event.*

The verb in Innu varies in gender, number, person and in obviation, as does the noun. More specifically, it also varies in tense, mode and in order, thus creating conjugations.

Furthermore, we recently decided to include in Level 1 information that is not essential for all non-specialist users, but that may interest some of them. This information is titled *Grammaire avancée* (advanced grammar),[23] as in (4), also from the chapter on elementary notions; it is in the section entitled *Les classes de mots* (parts of speech), and it comes after more basic explanations about kinds of word in Innu:

(4) Examples of more advanced information, at *Level 1*

> GRAMMAIRE AVANCÉE: On parle aussi, pour les *classes de mots*, de *catégories majeures* et de *catégories mineures*. Les catégories majeures sont celles qui regroupent les verbes, les noms et les prépositions; les catégories mineures regroupent les autres classes de mots. Les catégories majeures servent à exprimer le message du locuteur et elles ont un contenu lexical; les catégories mineures ont un contenu d'abord grammatical.
> On parle également de *classes ouvertes* pour les verbes, les noms et les adverbes, parce qu'on peut leur ajouter de nouveaux mots. Les autres classes sont *fermées*, parce qu'on peut plus difficilement leur ajouter de nouveaux mots.[24]

(source : Baraby et Drapeau, forthcoming, chapter on basic notions)

In these cases, the remarks are clearly identified, giving the user the choice of reading it or not.

At Level 1, there are also comparisons with other languages, when we judge it can help users to understand explanations about a given concept. It is of two types: comparison with languages like French and English, or comparison with other Algonquian languages. Another kind of "special" information that belongs at Level 1 concerns orthographical remarks.

The different kinds of special information at Level 1 are all presented in box frames, with different layouts or settings, depending on each rubric. Actually, in a printed grammar, we have to employ this kind of typography, because all information is given on the same plane. This is a situation where an electronic version has considerable advantages over a printed version, since it can present more than one plane or versions. However, despite difficulties inherent in a book version, we think it is possible to have a printed multilevel grammar, but it means using a great number of formatting tools and techniques. In the Innu grammar,

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[22] Translation: *From a syntactic point of view, the verb usually agrees with its subject and sometimes with its object. This agreement in gender, number, person and obviation is indicated by grammatical material added to the verb. Moreover, the verb may vary in order to indicate the tense of the action or even being described, as well as the modality (judgement that the speaker makes concerning what is being said*

[23] We got the idea of introducing more complex grammatical information aimed at non-specialist users from our experience in teaching French grammar to native speakers and teaching basic course in linguistics to Innu teachers. In both cases, there were always a number of students who wanted to go beyond the course matter. These kinds of remarks belong at Level 1, because they deal with grammatical information usually readily known by linguists.

[24] Translation: *Advanced grammar: Word classes can be divided into major categories and minor categories. Major categories include verbs, nouns and prepositions; minor categories include all other word classes. Major categories are used to express the message of the speaker and they contain lexical material; minor categories have mainly grammatical content.*

Verbs, nouns and adverbs are considered to be open classes since one can add new words to them while all other word classes are considered closed because it is much more difficult to add new words to them.

we have designed a sort of key corresponding to different types of information or rubrics, which we systematically use.

As for the rest of the grammatical description, aimed at the non-specialist user, it is given in plain text, without any special formatting, and it is written using a higher size of font.

As for most printed grammars, the content of Innu grammar is organized in chapters, sections, sub-sections, etc. Nevertheless, there is another question linked to the issue of the organization of grammatical content that may arise; it concerns both the organization of the grammar and the theoretical approach. Traditional grammars, and most grammars generally, are *structural*, meaning that descriptions are based on structures or forms, and not on functions. A grammar organized on the basis of parts of speech is a good example of a structural organization, just as is a description of verbs based on paradigms and inflections. On the other hand, a grammar that gives more importance to functions, to what one does with structures, how one constructs meanings in a language is a *functional grammar*; for instance: concept identification, message building, making up a message,[25] marking time, concepts of space and location, command strategies, etc. These two types of grammars are often seen as opposite theoretical approaches in describing language grammars. In our grammaticographic model, it is more a matter of perspectives according to which the grammatical content is organized, than a matter of opposing theoretical approaches. Furthermore, structural and functional approaches (or perspectives) may be quite complementary. Thus, for Innu grammar, we conceive of a mixed perspective, structural and functional, according to descriptive needs. Actually, our Innu grammar starts with chapters based on parts of speech, but other chapters are more functional (for example, a chapter about the meaning of modes and modalities). Some chapters may be more structural (noun and verb morphology), others more functional (semantics of modalities), still others both structural and functional at the same time. We refuse to be confined to one given theoretical approach, and we prefer to make use of what seems to be the best way to describe or explain what is going on in the language. After all, the main objective of a grammar written for speakers is the description of the language, not the defense of a particular linguistic or grammatical theory. In our Innu grammar, we adopt a more or less traditional approach, because it is what Innu speakers are familiar with, since they were schooled in French and were taught French grammar. It is supplemented with information coming from research carried out in Algonquian linguistics and adapted to a non-specialized audience. This point of view is not Eurocentric, but pragmatic: it is a question of building on what speakers already know and which is comparable in French (or English) and in Innu, before introducing new material, more features of Innu language structures. Since most Innu speakers, even Innu language teachers, have never been trained in the grammar of their language, they only have intuitive but no metalinguistic knowledge of it, which is why they have to "learn" about the functioning of their own language, to acquire how to think about it and how to talk about it.

Writing a grammar for non-specialists does not mean to oversimplify. Actually, it consists in vulgarizing specialized matter, to give access to it to those who are not familiar with descriptions aimed at linguists, and doing this is no easy task. It is often easier to use

[25] These first two examples come from *Collins Cobuild English* (Sinclair 2004), which is a professed functional grammar: "A grammar which puts together the patterns of the language and the things you can do with them is called a functional grammar. This is a functional grammar (. . .)" (Sinclair, 2004: v).

precise terminology, designed for specialists. Example (5) is an extract of Innu grammar introducing fundamentals of morphology:

(5) Extract of Innu grammar, chapter on elementary concepts, section on word formation

> Les langues du monde ne forment pas toutes leurs mots de la même façon. On appelle *morphologie* l'analyse de la formation des mots. Comme toutes les langues algonquiennes, et contrairement au français, l'innu a une morphologie très complexe.
> Par l'analyse de la formation des mots, ou l'*analyse morphologique*, on parvient à isoler les différentes parties d'un mot, chacune ayant une signification propre. On nomme *morphème* chaque partie indécomposable de mot dont on peut identifier le sens. Le morphème est ainsi dit la *plus petite unité* (ou *unité minimale*) porteuse de sens. Cette notion de *sens* rattachée au morphème est très importante : un mot peut en effet être découpé en parties, c'est-à-dire en morphèmes, en autant que chacune de ces parties signifie quelque chose. La signification d'un morphème peut aussi n'être que grammaticale : par exemple, dans *ashamat* 'les raquettes' et dans *atusseuat* 'ils travaillent', *-at* marque le pluriel alors que dans **atussepan** 'il travaillait', *-pan* marque le passé; les morphèmes *asham* et *atusse-* portent respectivement les sens de 'raquette' et 'travailler'.

(source : Baraby et Drapeau, forthcoming, chapter on basic notions)

In this type of reference grammar, we have to define notions such as *word*, *noun*, *verb*, *prefix*, *suffix*, etc. More challenging is the definition of other notions such as *transitivity*, important for the classification of verbs in Innu since in Algonquian languages, there are four classes of verbs based on animacy and transitivity. Of course, when addressing linguists, it is not necessary to explain what a transitive verb is, but the concept is not easily explained to non-specialists.[26]

Describing for laymen necessitates adaptation in matters of terminology, concepts, and also definitions. Thus, writing for speakers of a minority language implies taking them at a starting point, and in bringing them as far as they want to go, giving them some theoretical tools to better understand their language structures, so they can transfer this knowledge in their teaching. For minority languages, vulgarizing also means helping speakers develop metalinguistic knowledge they did not have the opportunity to learn while at school. Our experience with Innu teachers has shown that they are quite motivated to learn more about their language, as long as we take the time to explain what they need to learn in order to move forward. A good grammar aimed at speakers has to be written in a simple, clear and precise style, but simplifying does not mean less rigor in the description.

Secondary levels All other levels of the grammar, matter mostly intended for specialists or any users other than primary users, are less substantial, and are clearly identified by different kinds of formatting, such as letter-press, fonts, frames, colors, font size and indentation, headers, etc. In so doing, secondary level will be kept in the background, in such a

[26] We know this from our own experience in teaching French and Innu grammar, and from what others have told us about their endeavours to teach this concept to Innu speakers.

way that non-specialized reader will be able to skip non-essential material and focus on the main content. At the same time, those really interested in finding out more about specialized information will know where to find it.

To illustrate the kind of information aimed at linguists, we give in (6) and (7) extracts from our Innu grammar (chapter on modes and modalities). In (6), the information is intended to justify the use of a different term for a mode than what was traditionally used in Algonquian linguistics.

(6) Example of information pertaining to Level 2, addressed to linguists

LINGUISTIQUE : Dans un système de modalités épistémiques, la terminologie des modes doit pouvoir tenir compte des contextes précis d'utilisation de ces modes. Palmer (2001, p. 24-25) rejette le terme 'dubitatif' dans le cas d'une affirmation qui s'appuie sur l'observation. Pour des formes qui, comme celles de l'innu en *-tshe* et *-kupan*, n'indiquent pas un doute formel, il propose plutôt le terme « *deductive* ». Ainsi, dans l'exemple anglais *John must be in his office* 'John doit être à son bureau', Palmer souligne que le locuteur porte un jugement ferme découlant d'une preuve **observable** : par exemple, *parce que les lumières du bureau sont allumées, parce que John n'est pas chez lui, etc*. Ce jugement basé sur la déduction est différent de celui qui implique l'emploi de *may* ('peut, peut-être') *John may be in his office* 'John est peut-être dans son bureau' (spéculation) ou encore, l'emploi de *will* (conclusion raisonnable basée sur une connaissance partagée) *John'll be in his office* 'Jean est sûrement dans son bureau' (*parce qu'il commence toujours à huit heures, parce qu'il est un travailleur acharné, etc.*) (Palmer 2001, p. 25). Dans une analyse logique des modalités, le mode DÉDUCTIF de l'innu correspond à la *nécessité* épistémique, qui est basée sur la déduction.
(source : Baraby et Drapeau, forthcoming, chapter on modes and modalities)

In (7), the information is given to keep track of historical data for a special form of imperative in Innu that is not well known in Algonquian linguistics.

(7) Example of information pertaining to Level 2, addressed to linguists

HISTORIQUE : L'impératif en *–me* est rapporté par Goddard (1979:90) pour l'ancien Unami et dans Lemoine (1901:15ff,cité dans Goddard) pour l'innu. Goddard l'interprète comme un impératif futur et il croit que l'impératif en *–me* est plus ancien que celui en *–hk*. En 1988, Goddard mentionne la présence de l'impératif en *–me* dans la grammaire de l'algonquin du XVII^{e} siècle du père Nicolas (Pentland 1988:47-50).

(source : Baraby et Drapeau, forthcoming, chapter on modes and modalities)

Most of the information addressed to linguists has the same format, except for subtitles.

In sum, each type of information must have the same layout over the whole grammar, in order for the reader to be able to recognize it easily and decide if he or she needs to read it or not.

4.3 Language used for description and metalanguage There is one point that is not often discussed in grammaticography. It concerns the language in which the grammar is written, as well as the language used for grammatical terminology or for metalanguage, what Lehmann (1989:134) prefers to call "background language". For grammars intended for linguists, it may not be an issue; since the language to be described is not mastered by most potential users, a grammarian generally prefers to use a more widespread language such as English. The problem is posed differently in case of grammars mainly written for non-specialized speakers of a language. Should the grammarian use the language that is the object of the description as background language or should he or she use a widespread language such as English or French? Both solutions are acceptable, depending on the specific context. If the minority language is used, speakers will need to learn a specialized grammatical lexicon in the language, and this may prove to be a daunting task. Moreover, writing a minority language grammar using the minority language as background language limits the accessibility of the description to speakers – in fact to readers – of the language.

For our grammar of Innu, the background language used is French, because speakers are bilingual (mostly in Innu and French); they are schooled in French, where they learn formal French grammar. As for grammatical terminology, we utilize traditional French grammatical terminology, in so far as it corresponds adequately to Innu grammar. Traditional French grammatical terminology is useful for quasi-universal linguistic or grammatical concepts, but it is insufficient in a number of cases, since Algonquian languages are quite distant from European languages, genetically and typologically. To solve this issue, we tend to search for more suitable terminology in either Algonquian linguistics or in linguistic typology. But since most of the linguistic documents are published in English, once we have found a suitable term, we have to find a good French equivalent. In fact, finding an adequate terminology, especially in French, to describe a language for non-specialist speakers is quite challenging.

5 A printed or an electronic grammar? In the preceding sections, we presented the main characteristics or our grammaticographic model, that is, who the end users of the type of grammar we are developing are going to be – speakers of minority languages, as well as linguists – and how it is possible to meet such different users' needs, our key proposition being to produce a multilevel grammar, with the first and basic level aimed at non-specialist speakers, other levels aiming other users, including linguists. Originally, we started developing our grammaticographic model within the scope of the Innu grammar project, whose primary objective was to produce a reference grammar book, and we therefore came up primarily with solutions for printed grammars. In the meantime, we started contemplating what electronic media could bring to minority language grammar projects, inspired by a project of an online grammar that is being elaborated for Eastern Cree, a related language to Innu.[27] Indeed, we still believe both kinds of project – printed and electronic grammars – are worthwhile for minority language speakers, having positive and negative aspects, according to each situation or to the objective of the grammatical description. Because we believed the needs in this matter were important, we pursued our initial project, develop-

[27] Eastern Cree is spoken in Quebec, on James Bay and inland; it is part of the Cree-Innu-Naskapi continuum, and is very close to Innu; speakers of both language living in contiguous territories are able to understand each other. For more information about the online grammar project of Cree language, see http://www.eastcree.org/

ing a grammaticography for printed grammars. We know, in fact, from the specific Innu situation, as well as from other contexts with which we are familiar, that many minority language members prefer to have access to grammar books, rather than online grammars. But in this process, we have always kept in mind the possibility of applying to electronic grammars some of the grammaticographic principles and solutions we were developing for printed grammars.

In the following sections, we first examine both positive and negative aspects which we have raised for both types of grammars, in particular in the situation of minority languages. In fact, we ask the following question: are these two products really opposed or are they in fact complementary? As well, we consider how electronic (or online) grammatical media might be interesting for a multilevel model of grammar.

5.1 Positive and negative aspects of printed and electronic grammars In a grammaticograhy aimed at linguists, the advantages of electronic grammars may be obvious, though not without problems. We do not intend to repeat here what has already been discussed elsewhere, except for the context of minority language grammars for non-specialists. In this particular case, criteria in deciding to develop an electronic grammar are not exactly the same as developing one aimed squarely at linguists.

Evaluation of electronic grammars in general To summarize the positive and negative aspects of the online publication of reference grammars, we will take as a starting point some of Noonan's (2006) arguments, who evaluates this possibility, but with a linguistic audience in mind:

> [...] online publication of grammars and dictionaries has a number of advantages over paper publication: online grammars and dictionaries can easily be updated and revised [...]. They can also be made available to a wider audience (especially if access is free) than is possible with paper publication. And lastly, online, or at least electronic, publication can facilitate the addition of audio and visual materials to the written text of the grammar.
>
> There are two problems with online publication. The first is that, in many cases, it is not evaluated as highly as paper publication for purposes of hiring, tenure, and promotion. [...] The second problem relates to the relative impermanence of electronic and online publication media (Noonan 2006:364).

Negative aspects of electronic grammar for non-specialist users It turns out that the advantages discussed by Noonan (2006) are also relevant for grammars intended for speakers, but before considering these, we wish to examine a number of problems with online grammars for the principal audience we have in mind, starting with those identified in Noonan (2006), as well as a few of our own.

The first issue brought up by Noonan (2006) is the potential hesitancy of some linguists to publish online grammatical descriptions, because this kind of work is less valued (for hiring, tenure, promotions, etc.) than printed publication. We should add to this the fact that publications addressed to non-linguist, printed or online, are also much less valued than are more specialized works. Minority language grammarians usually have to go beyond

these considerations; otherwise, no under-described language would ever be documented or described.

As for the second of Noonan (2006) disadvantages, we think specialists of electronic grammaticography are well aware of the issue and are working to develop more enduring formats. Here, we must take into account the fact that not all linguists have the technical training and skills to elaborate electronic grammatical tools, as Weber (2006:459) admits. As he points out: "Grammar writers need hospitable authoring environments, with tools that are powerful and flexible, yet reasonably easy to learn and use. Until these are available we labor under the limitations of ink-on-paper." Actually, in the particular context of minority languages, where financial resources may be limited – even for printed grammars – an online grammar, with the complex infrastructure it requires, is a big challenge, as much for grammarians as for the speakers of these languages.

More specifically, we believe developing electronic grammars for minority languages poses a number of specific problems and difficulties that do not necessarily occur for grammars aimed at linguists, or for grammars of widely spoken languages.

First of all, producing electronic grammars is not within every linguistic community's means, since it requires human and material (or financial) resources that are not available everywhere. As a matter of fact, members of these communities may not be familiar with new technologies, so they prefer something more traditional, such as grammar books.[28] Moreover, experts in technology may be lacking in these communities. As well, new technologies or access to the Internet may be inadequate (for example, there may be no access to high-speed transmission lines). These deficiencies might be temporary, being only a question of time or of one generation. For instance, Innu language professionals are still more familiar with printed material than with electronic material, but Innu youngsters are good users of all new technologies, including Internet: they like chat rooms, e-mails, etc. So, we expect they will be quite interested in reference material using Internet or other electronic technologies, in a more or less near future.[29]

Electronic grammars do not necessarily alleviate the grammarian's task; on the contrary, it probably increases it, since in electronic grammars, there are no page limits, and because it is tempting to add information in various ways. There is therefore the danger of going too far, and in never completing the grammar. A good solution to avoid this pitfall is to make accessible an alpha version of the grammar, as work in progress, even if the description is not completed. Or to plan publications of parts of the grammar, before completion of the whole, as discussed in Nordhoff (2008).

As a matter of fact, it should be kept in mind that any good grammatical description, whether a printed or an electronic one, is based on same prerequisites: clear choices concerning end users and objectives, good access to linguistic data and examples, accuracy and soundness of the description and analysis of the language.

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[28] Here, we are not talking of *producing* such a book, but of *using* or *reading* the document once it is published. However, we are well aware that perception about electronic products is evolving rapidly, mostly among young generations, and that present reservations may change faster than what was first thought.

[29] As a matter of fact, the Institut Tshakapesh is now collaborating with Marie-Odile Junker (Carleton University) and http://www.eastcree.org/ to develop different kinds of electronic grammatical tools for Innu: short grammatical explanations (*capsules grammaticales*), a grammatical blog, grammatical exercises, use of Facebook, etc. We will also participate in this project. It will be a good example of complementariness between printed and electronic material to describe the grammar of a language.

In spite of these inconveniences, we foresee that electronic grammars will become more important in grammaticography, even for grammars addressed to non-specialized speakers, at least where computers and Internet are available. And thanks to the joint efforts of many specialists in the domain of threatened languages, these tools will become accessible in a larger number of contexts.

Positives aspect of electronic media for non-specialist grammar users Proponents of electronic tools for grammatical description especially underline the flexibility and the accessibility provided by these tools, and these points are certainly of great importance, for all types of grammars, intended as much for linguists as for non-specialists. Flexibility will be the main advantage of such a technology for our multilevel grammar, which we will explain in greater detail below. But first, we focus on flexibility and accessibility, in a more general way.

Flexibility of electronic grammars for speakers With electronic reference grammars, flexibility might be seen from two points of view, that of the authors, and that of the users

From the grammarian's perspective, electronic publishing gives better opportunities of revising and updating the grammatical document, as new information or knowledge about the language is made available, and this is quite important for the purpose of language documentation. As an interesting consequence, there is the possibility of making available the grammar before it is completed. In doing so, the grammarian is able to validate his work: first, with the speakers, allowing him to verify the appropriateness of his description or analysis, or the relevance of the examples or linguistic data used; secondly, with the aimed-at users, to verify the readability of the grammatical text itself.

Besides the possibility of up-dating a grammatical description, online grammars offer much more: a whole range of potential interactions between authors and users. These interactions can take different forms, such as the social media of Web 2.0;[30] it can be integrated in the interface of an online grammar, or linked to it (Good this volume, Drude this volume). Of course, interactions between grammarians and grammar users will depend on each linguistic situation, and it must be well organized and supervised, to avoid any loss of control over the grammatical content.

Printed grammars are linear, meaning that each document is organized in a single way, as each author has decided to present his work, for instance, from chapters to chapters, sections to sections, etc. The possibilities in elaborating the organization of electronic grammars are more varied, since they can provide different perspectives or different ways of navigating through the text.

From the user's point of view, online grammars might offer a flexible way to get to the required grammatical information; in other words, the user can adapt the grammar to his or her own needs, without getting lost in a profusion of grammatical information. The possibility of easily navigating through an electronic grammar is also an advantage over traditional printed grammars; this has to do with the next point, accessibility of the grammatical description.

[30] Supervising the project of the Cree on-line grammar, but also collaborating with Innu speakers, Marie-Odile Junker, is now working with social media and devising this kind of interactive on-line grammatical material aimed at non-specialists.

Accessibility of electronic grammars for speakers The fact that electronic grammars, especially online grammars, are more easily accessible than printed grammars seems evident. But this aspect may also be looked at from different vantage points.

First, we must take into account the fact that young people in minority language communities are quite attracted by the new media. Therefore, even if persons who are now working on a language – teaching or describing it – are not at ease with these new media, they will eventually have to take a stand on the matter. They will have to think not only about the future of their language, but also about the future of the young generations to whom they have to transmit it. Those who are not familiar with new technologies might not see their importance in youngsters' lives but staking on new technologies in a language preservation program is a good investment, since it could meet young speakers' interests.

Secondly, as mentioned previously, electronic grammars give an easy access to grammatical content; more precisely, it permits easy navigation through the grammatical text. In traditional printed grammars, one needs good tables of content, indices, cross-references, etc. In electronic grammars, such means are easier to use. As well, other kinds of links may be added; for example, to more examples, to texts illustrating the description, to a lexicon or a dictionary, or to a conjugation guide, to name but a few.

5.2 A MULTILEVEL GRAMMAR FOR INNU SPEAKERS We will now explain how we see this type of grammar for the grammaticographic model we propose, based on our experience with Innu.

In the case of Innu, when we started to work on the grammar intended for the speakers, we did not even think of the possibility of an electronic or online grammar since the only possibility at the time was a printed grammar. We now have to also consider new technologies, if only to take into account the needs and interests of younger speakers.

A PRINTED OR AN ON-LINE INNU GRAMMAR? Developing a grammar for a language that is under-described is a long-term task: often one starts from scratch, and, as the description progresses, it becomes "larger and larger as time goes on, as it is a task for which there is no logical endpoint" (Rice 2006:400). For this reason, the grammar of Innu is not yet completed. And because the project was, from the beginning, to produce a printed grammar, we will achieve this objective, at least partly, to meet actual users' expectations. In fact, our principal end users, Innu language teachers, are currently more at ease with traditional grammatical tools, i.e. books. But, we are also thinking about future users, who might be more familiar with new technologies, and probably would prefer such media. Therefore, we are contemplating a compromise, which consists in publishing, as soon as possible, a first volume of the Innu grammar, which would be mostly a description of basic structures, basic parts of speech (nouns, pronouns, verbs), as well as a description of inflections, since inflectional morphology is quite complex. And subsequently, we would pursue the grammatical description online.

Therefore, we see printed and online projects as complementary, rather than opposed. This way may constitute a good transition between both kinds of production. Besides writing an online grammar to complement a printed volume, we may think about other ways to see future grammatical products, for instance, interactive tools, or grammatical sketches.

Building up an electronic infrastructure for Innu grammar is possible because the resources are available: Innu speakers have access to computers, at home or in schools; Innu language specialists are working closely with those who are developing a Website for the Cree language, which includes a dictionary and a grammar, and that makes it possible to benefit from what was developed for Cree, which is close to Innu.

An electronic grammar of Innu language Even if we are not an expert in new technologies, particularly in the conception of electronic grammatical infrastructures, we are well aware that these technologies provide a very interesting option for our model of multilevel grammar. We will not discuss here which technologies could be used to make this kind of project achievable, but we will try to illustrate the possibilities we envisage with examples of Innu grammar.

An electronic multilevel or multilayer grammar The main characteristics of our grammaticographic model follow from the objective which consists in meeting as much as possible the needs of non-specialized users while adequately documenting the grammar of their language. To achieve this objective, we have proposed a grammar with different levels of reading or use, for different types of audience. Applying such a model to printed grammars means employing various typographical processes to differentiate each level. In fact, there are not many ways to reflect in a printed grammar the layered organization we wish for, since printed documents are basically linear. Furthermore, the various techniques that we can imagine are expensive, for example the use of colors, or the fact of requiring specialists such as book designers.

Organizing a multilayered grammar is much easier with electronic media, once the infrastructure for a grammar is available, since each level (or layer) of information can be provided on different pages, with links between each level. In this way, the main text is not encumbered with unneeded information. In fact, all information aimed at other users than the principal end user – advanced learner or speaker, linguist, second language learner, etc. – is found in other layers, accessible by simply clicking on special tabs. In this way, first level users will not be diverted or confused with a profusion of information. Moreover, it becomes possible for the user to "follow his or her own path to explore" the grammatical description (Nordhoff 2008:315). As for specialists, an electronic document may provide links to other publications, such as academic articles, on particular linguistic structures described in the grammar.

For Innu, for example, there exists a large lexical database as well as a conjugational guide, with links between both. We imagine that associating a grammar with the above tools is undoubtedly feasible.

Accessible and flexible use of an online grammar Besides allowing navigating in the grammar from one level to another, electronic grammars are easier to use even with a single level, permitting accessible cross-referencing, links to a glossary of terminological terms, to a lexicon or to verb paradigms, etc.

Moreover, the presentation of the content of the grammar following both structural and functional perspectives is facilitated in an electronic grammar, with the possibility of links between both perspectives. To give a concrete example, in Innu, 80 % of words are verbs.

As well, the verbal system is quite complex, with a rich derivational and inflectional morphology. Each verb has many conjugations, belonging to one of four verb classes, three orders of conjugations, many modes and tenses. For example, our *Guide des conjugaisons*, which we have developed, provides only verb paradigms, without any grammatical explanations, and yet is about 80 pages long. Also, to describe the verbs, we cannot simply present the morphology, but we must also describe the context of use of some features of the verbal system: orders refer to the syntax, the semantics and the pragmatics; modes and modalities refer to semantics, and so on. Making choices about the organization of the grammar, the ordering of the chapters, etc., is not easy, since there are different options. Weber (2000:2) observed:

> The linear organization of grammars in no way reflects the structure of language itself. Language is an *organic* whole, a complex of subsystems so tightly interwoven that change in one part generally has consequences in many other parts. Forcing a grammar into an outline is, in itself, a misrepresentation of its structure (one that I suspect has led to considerable frustration for most grammar writers).

In the specific case of Innu verbs, an electronic grammar could be more flexible than a printed grammar. We know that Innu teachers are not at ease with the *Guide des conjugaisons*, as it exists now. So we have to find a better way to present conjugations.

Another point to consider is the examples that illustrate the description or help in understanding the explanations. In a grammar addressed to non-specialists, it is essential to provide a good set of examples. And this is even more important for under-described or under-documented languages. The number of examples and the way they are presented are problematic in printed grammars. For instance, in a grammar written for a large audience, one would not find linguistic annotations such as are usually found in descriptions aimed primarily at linguists. In electronic grammars, there is more latitude in the matter, and there is the opportunity to link examples or explanations to other corpora or texts.

As another option, in the Innu grammar, we envisage adding links to grammatical exercises, and perhaps different kinds of interaction between the grammarians and the users, such as blogs, and on-line discussion groups.

Some final remarks At present, Innu speakers are expecting a printed grammar of their language, mostly because they are more used to this type of work. Therefore, we want to meet their needs in producing, as soon as possible, a first volume of the Innu grammar. But we know that it would require more time and work to achieve a more complete description of the grammar. Thus we are now contemplating the idea of publishing other parts of the grammar using electronic media, probably on Internet. As we have said previously, printed and electronic grammars should be seen as complementary rather than opposing tools. In some linguistic contexts, it is more realistic to start with a printed grammar book before having the resources to develop a grammar using new technologies.

If developing an electronic grammar provides a number of solutions to various issues of grammar publication, it is also a real challenge. It will not make the writing of descriptions less burdensome. Moreover, it requires various resources, building the infrastructure with the new media (electronic or online), in other words, people with good technical skills, as

well as software to manage the elaboration of the grammar. And for non-linguists as eventual readership it is important to have a well-designed format, with attractive presentations, as we have proposed for a printed version, and this may require other kinds of expertise.

6 Conclusion Minority language situations are not all the same. Therefore we do not propose solutions for grammar writing that suit every under-described language. But we think it is vitally important to take into account the role of speakers in grammaticography, because they are the main actors in language maintenance and transmission. From our experience as a grammarian of Innu, we have elaborated a model of a multilevel grammar, which places the speakers of the language in the foreground, as well as considering other users, including linguists. Even if our grammaticographic model was first conceived for printed grammars, we have considered the possibility of applying it to electronic or online grammars; in other words, to apply electronic solutions to this model.

Is an electronic grammar a better medium for a multilevel grammar than a printed grammar? There is no simple answer to this question. Developing a grammar on the web may pose specific challenges, but it also shares problems with writing a printed grammar book. Instead of seeing both as being opposed, we believe they are complementary. In some linguistic communities, even printing a grammar book is a complex task, whereas others are already on the way of producing online grammars. The most important is to keep in mind the objective of giving the speakers a good grammatical description, on paper or online.

We believe that an online grammar could be a good solution to carry out a multilevel (or multilayered) model of grammar. But it involves resources, i.e. experts, software and hardware, etc., that are not necessarily within the reach of all grammarians or minority language communities.

Looking to the future, and taking in consideration the rapid progression of technological tools, we can anticipate that various new technologies will become more and more accessible. Also, in view of the interest of younger generations in new technologies, we think online grammars aimed at non-specialists will have a bright future.

In our view, writing a high-quality reference grammar, whether electronic or printed, may be a good opportunity to transmit grammatical knowledge from linguists to speakers, a way to make sure that such knowledge will not remain ensconced in academia.

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Part II.

Applications

5

Language Documentation & Conservation Special Publication No. 4 (October 2012)
Electronic Grammaticography ed. by Sebastian Nordhoff pages 103-128
http://nflrc.hawaii.edu/ldc
http://hdl.handle.net/10125/4532
http://nflrc.hawaii.edu/ldc/sp04

Grammars for the people, by the people, made easier using PAWS and XLingPaper

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The task of documenting the minority languages of the world, many of them endangered, is daunting. Further, it is most likely impossible to expect that linguists can go to every language and write a reference grammar for it. At the same time, the indigenous people are becoming more educated and more interested in working on their own languages. This paper describes a computational tool that teaches native speakers about various linguistic constructions, has them enter data from their language and answer simple questions about it, and then produces a draft of a practical grammar of the language. This grammar can be edited for publishing electronically and/or on paper and is useful for the people themselves as well as by linguists.

The underlying XML technology allows much of the complexity to be hidden from the user, while providing multiple views and outputs possible from the same data. The marked-up XML files are archivable and usable by many XML editors. Localization and customization are also possible.

1 Introduction Linguists are scrambling to try to meet the need of documenting and describing the endangered languages of the world, as well as many of the other minority languages. Further, it is fair to assume it would be impossible for linguists to go to every language and write a reference grammar for it. The task simply takes too much time and there are not enough trained linguists available. Even if the linguists could accomplish the task of language documentation and description, current methods would not be productive enough, since documents written in English for linguists do little to help preserve a language.

At the same time, the indigenous people want to be involved as they are becoming more educated and more interested in working on their own languages. A different type of grammar is needed: one that serves the language community, describes the language in general terms, and is also useful to linguists for extracting data for analysis. This type of grammar has the potential to revitalize the use of a language as the people realize their language is a "real" language worthy of use because it has a grammar and a dictionary like the national language.

This paper describes a computational tool called PAWS (Parser and Writer for Syntax) that can be used, especially in a workshop setting, to teach native speakers about various

linguistic constructions, have them enter data from their language and answer simple questions about it, and then produce a draft of a practical grammar of the language. Currently PAWS only runs on Windows operating systems. It is available at http://carla.sil.org/paws.htm.

The practical grammar style is illustrated in section 2. Section 3 details the user interface for input and how to edit the output using the XLingPaper authoring tool (Black 2009).[1] Section 4 then explains how it all works computationally.

2 PRACTICAL GRAMMARS Practical grammars, also known as popular grammars, are designed for use by the native speakers in the language community. As such, the grammars should be written using the national language for the explanations and glosses. The version described here includes additional material to provide some pedagogy for the reader. Moreover, numerous tables and data in interlinear format and description of the constructions make it useful to linguists and bilingual teachers as well.

2.1 GENERAL STRUCTURE A practical grammar consists mostly of data with some prose explanation. Information about single words or morphemes is usually presented in tables, but all longer examples are given in interlinear format. This format is a bit different than that found in most linguistic publications in order to make it most useful to and understandable by native speakers of the language. Four lines are used: the first line gives the vernacular words, without breaking them into morphemes, as morpheme breaks could be very confusing to the native speaker. The second line is the gloss of the word, with any additional words needed in the gloss language separated by periods. The third line gives the morpheme gloss with normal linguistic abbreviations and conventional symbols like hyphens separating the glosses for each morpheme. This third line is especially for linguists, but is given lower than the word gloss to make it easier for the speakers of the language and bilinguals to skip over if they so choose. The individual morphemes will usually be listed in separate tables to enable the linguists to parse the words, as exemplified in (1)-(2). (It would also be possible for the author to add a line to the grammar output giving the vernacular morphemes between hyphens, but this should come after the word gloss line and before the morpheme gloss line if included.) Finally, a free translation is given on the fourth line of the interlinear. This four-line structure is illustrated schematically in (1).

(1) VERNACULAR WORDS *word* *word* *word*
LITERAL WORD GLOSSES *'gloss'* *'gloss'* *'gloss'*
MORPHEME GLOSSES 'PRE-ROOT-SUF' 'PRE-ROOT-SUF' 'PRE-ROOT-SUF'
FREE TRANSLATION free translation phrase or sentence

A completed interlinear example from Isthmus Zapotec is shown in (2):

(2) *Gudixe* *Juan chii bexu ri'* *lu* *bi'chibe*
paid *John ten peso those face his.brother*
COMPL-pay John ten peso this to brother-3PL
'John paid those ten pesos to his brother.'

[1] For more on XLingPaper, see http://www.xlingpaper.org/.

Person	**Possessor Pronouns**	**Gloss**
first	du	'ours (exclusive)'
	nu	'ours (inclusive)'
second	tu	'yours (PL)'
third	be	'his/hers (person)'
	me	'his/hers (animal)'
	ni	'its (thing)'
	cabe	'theirs (persons)'
	came	'theirs (animals)'
	cani	'its (things)'

TABLE 1.: Dependent pronoun forms of Isthmus Zapotec

Type of feature	**Feature**	**Form**
aspect	completive	bi-/gu-
	habitual	r-/ri-/ru-
	incompletive (future)	za-/zi-/zi-/zu-
	perfect	hua-/huay-
	potential	gu-/gui-/Ø
	progressive	ca-/cay-/cu-
	stative	na-
mood	imperative	la-
	irrealis	ni-/ñ-

TABLE 2.: Isthmus Zapotec inflection features

One or more tables listing the dependent pronoun forms, as illustrated in Table 1 for Isthmus Zapotec, document this information in a central place and aid the linguist in parsing the words in the interlinear examples.[2]

The PAWS interface also asks the user to check off the inflection features used in their language. This is output in a table such as shown in Table 2 for Isthmus Zapotec.

Note that judgments on the grammaticality of data, usually noted by * and ?, are not used in the practical grammar in order to avoid confusion for the language community. Instead, the prose description of the construction is used to make the distribution clear. The prose is meant to be a-theoretical, but complete enough to allow linguists to apply their theory to the data. A descriptive style grammar also has a longer and wider useful life since it is not limited to the applicability of any particular linguistic theory.

At the end of the grammar, we suggest the addition of several native texts from various genres. This not only allows the language community to identify with the grammar, but also provides examples of sentences in a larger discourse context for the linguist. We suggest a three part presentation of each text to best meet the needs of each audience:

1. Present the text in the vernacular language as a whole first, so the native speakers can appreciate it.

[2] First and second person singular forms are not listed in the table because they cause a change in the noun root. Such details need to be explained separately while editing the grammar output.

2. Present the interlinear form, as in the examples throughout the grammar.
3. Give a free translation as a whole, so the non-native speaker can appreciate more about the culture.

The output from PAWS does not include any such texts, but it does have a section where the user is encouraged to add them.

2.2 Impact on a language community We have mentioned the importance of completing language description for the endangered languages. Even when a language has been described in English and it is not in imminent danger, a practical grammar written for the language community can have a profound impact. This was clearly demonstrated when the first edition of the practical grammar for Isthmus Zapotec was dedicated in January, 1999 (Pickett et al. 1998).

While Zapotec speakers in general do feel inferior to Spanish speakers, Isthmus Zapotec is the prestige variety of Zapotec. Further, the grammar of the language had been described quite well by Velma Pickett in her dissertation (Pickett 1959) and in a number of other articles. Still, Zapotec speaker Vicente Marcial Cerqueda came to Velma and to Cheryl Black and asked for help in writing a grammar in Spanish for his people. He wanted his people to realize that they did not have to abandon their language and only teach their children Spanish. The grammar needed to be presented in a simple, clear and correct form, so that they could understand that while their mother tongue is distinct from Spanish in many ways, it has a rich and complete structure just like all the other languages of the world.

We are happy to say that Vicente's goals were substantially realized. When the practical grammar was dedicated, there was a big celebration in Juchitán, Oaxaca, Mexico. Over 100 Zapotecs in full native dress crowded into the auditorium of the Casa de la Cultura. The top mariachi band came out of retirement to play for the dedication. The whole program was videotaped and televised later in its entirety throughout the region. The people stood in a long line afterward to purchase their copy of the grammar and have it autographed by all three coauthors. The next day, there was a radio talk show about the grammar. There were speakers from four different varieties of Zapotec on the air. They would open to a particular page and discuss the construction described there, saying for example, "It says on page 20 that Isthmus has a plural marker *ca* before the noun. In my language we say..." At the church service we attended on Sunday, people were happy that the grammar was presented because they could now use their Zapotec New Testaments in the public church service instead of just reading it at home. Interest and pride in their language was clearly restored.

A further encouragement came the following week when a dedication service was held at the *Universidad Nacional Autónoma de México* in Mexico City: One of the speakers from the university commented that this grammar, even though meant for the people, is useful for the Mexican linguists as well because the data is presented in interlinear format and the IPA charts are included. Our goal of producing a single grammar that could meet both needs was accomplished.

3 What the user sees Turning now to the implementation of PAWS, when the practical grammar option is selected, only the teaching and questions relevant to writing the grammar are presented to the user. There is a series of fifty-seven interactive web pages for the user to complete. The output is a draft of a practical grammar for their language based on their answers and sample data, which is intended to be further edited and enhanced for publishing.

3.1 Interactive pages The PAWS program contains a series of interactive pages which teach some linguistics and then ask questions about the various constructions. The program initially assumes default answers based on the word order typology of the language, but it allows for exceptions.

On most pages, there is a brief instruction on the construction with illustrative examples, then a series of multiple-choice questions about that construction for the language the user is working on. The number of questions asked depends upon how previous questions were answered. These answers are recorded and later used to give the prose explanation about the distribution of the construction in their language. It also asks the user to enter sample data for the various constructions, and records this data for the examples in the grammar.

Figures 1-5 show one such page for how possessors are handled within nominal phrases. We show what the user sees when they have chosen to only produce a practical grammar output. (The PAWS program can also produce a PC-PATR grammar output.[3] See McConnel (1995) for more on PC-PATR.)

[3] PC-PATR is an implementation of the unification-based PATR-II computational linguistic formalism (Shieber 1986). In addition, it is augmented with logical constraints on feature nodes and a priority union operation. The "PC" part of the name reflects the fact that it is designed to be used on personal computers (as opposed to mainframe or other large computers common at the time it was written). It is available for MS-DOS, Microsoft Windows, Macintosh, and Unix.

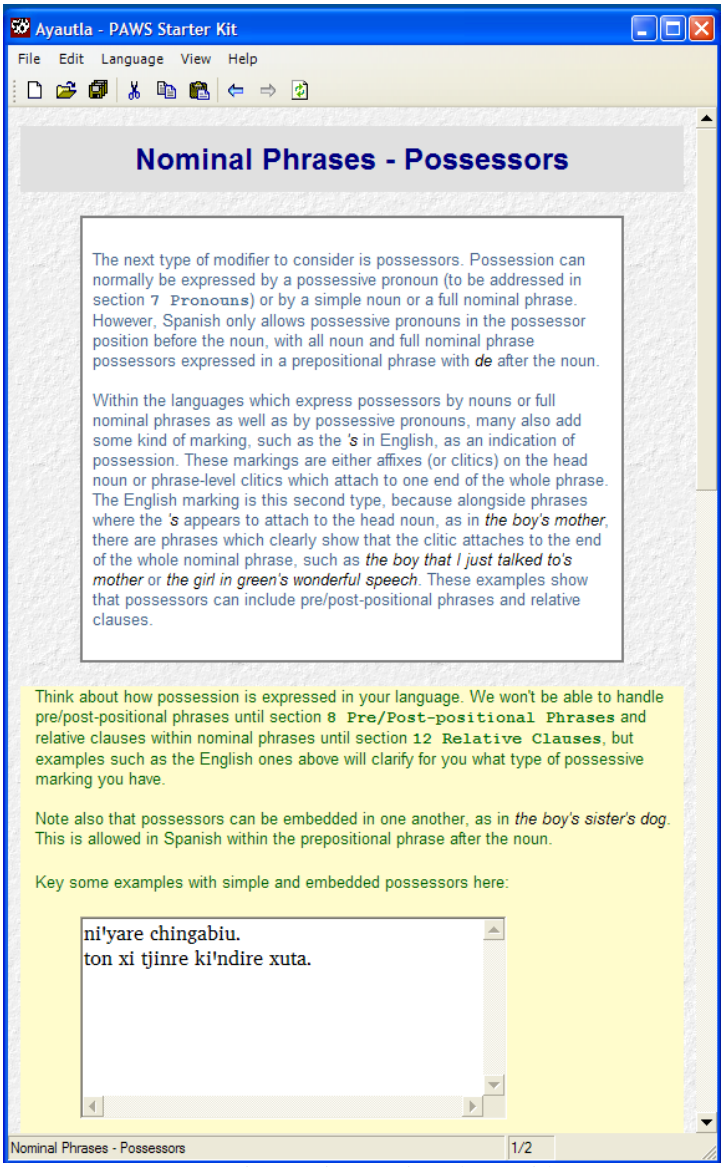

FIGURE 1.: An instruction section along with a request to enter sample data

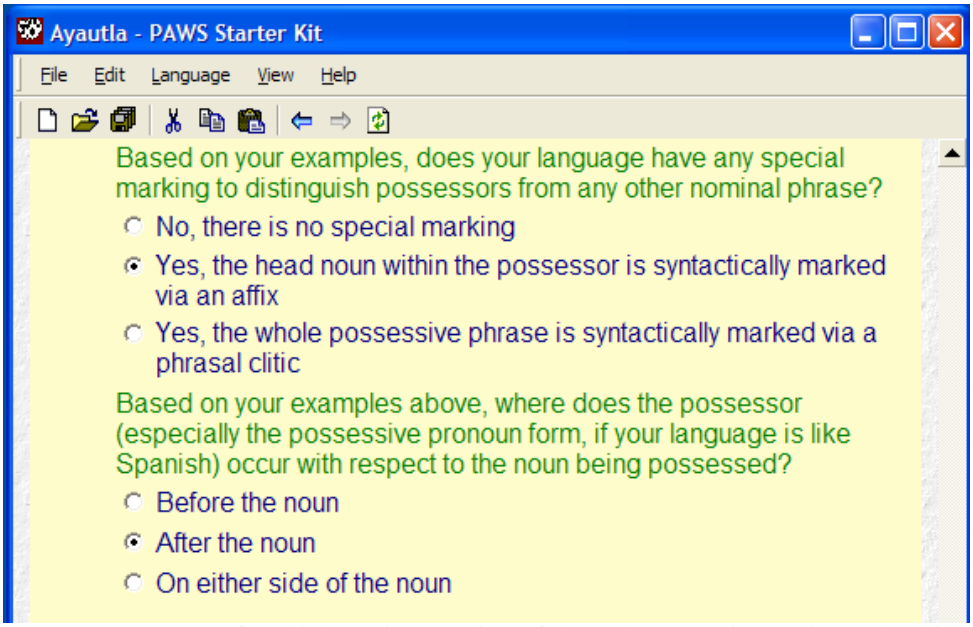

FIGURE 2.: Two sets of multiple choice questions, followed by more instruction and a third multiple choice question.

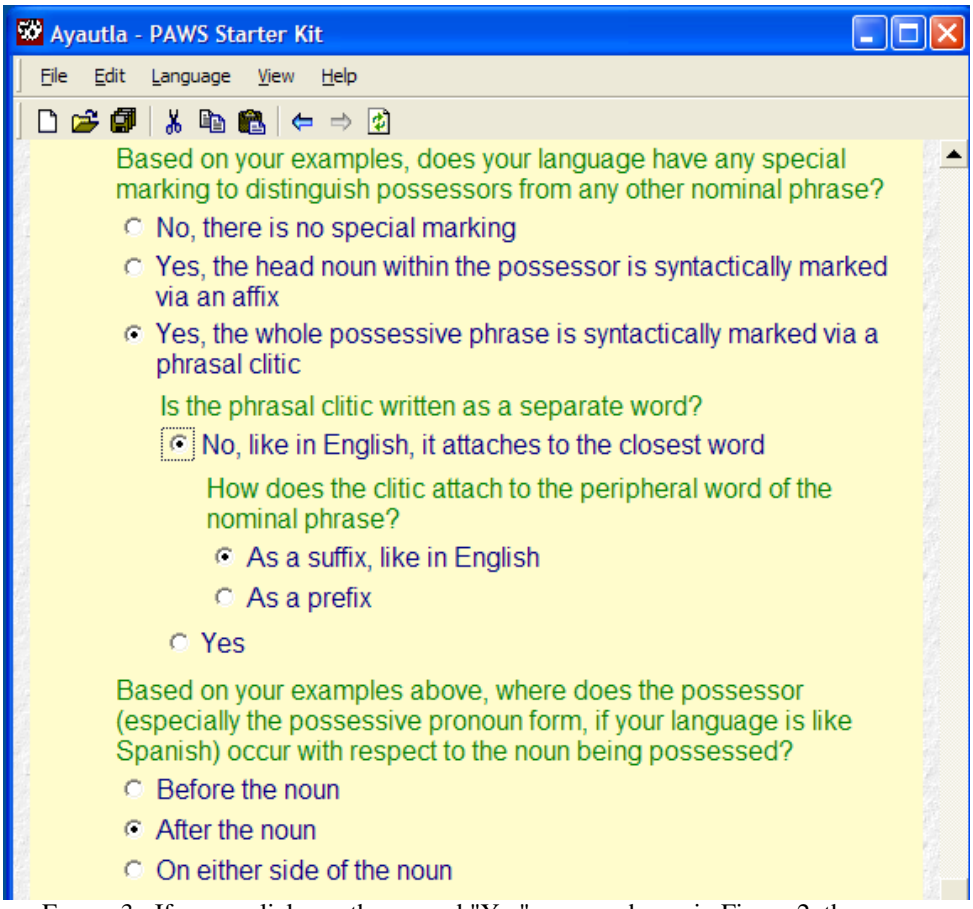

FIGURE 3.: If a user clicks on the second "Yes" answer shown in Figure 2, then more questions are asked (due to the fact that more information is needed about the nature of the phrasal clitic).

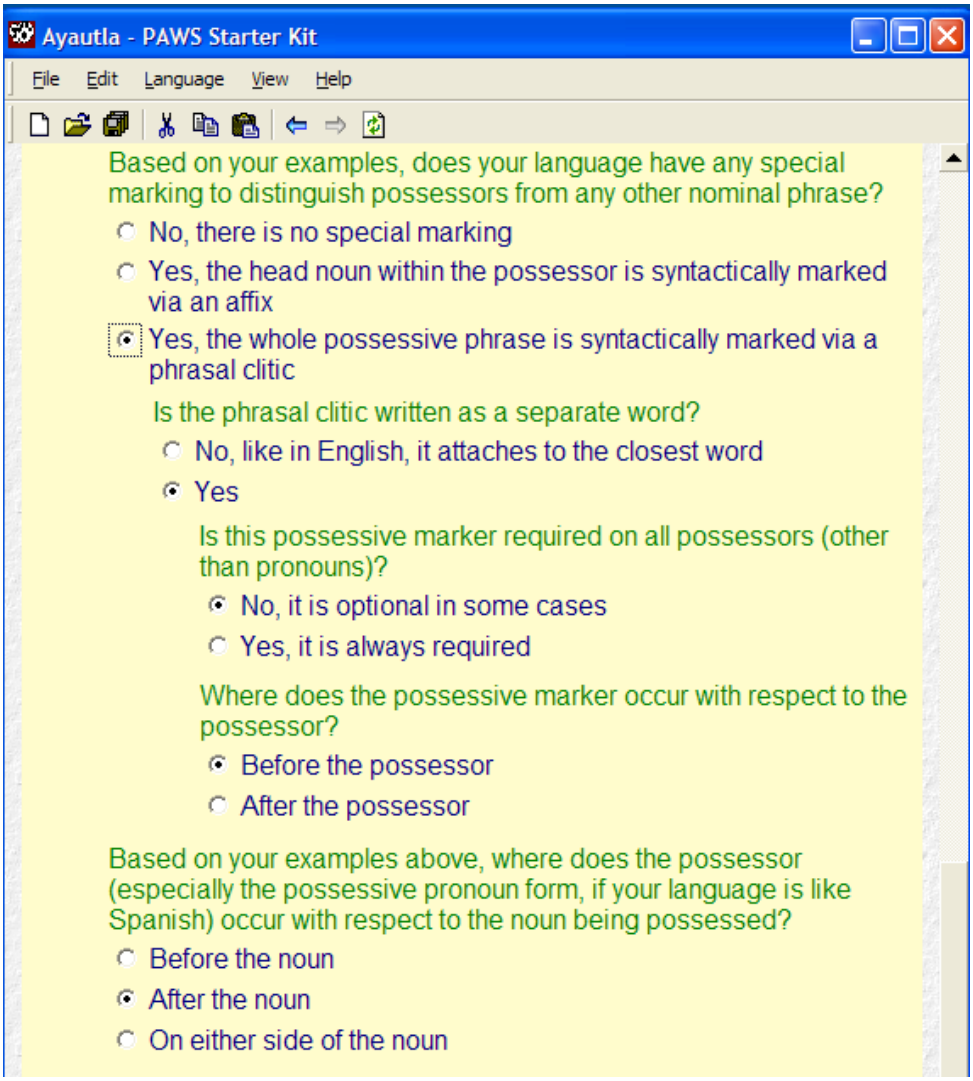

FIGURE 4.: If the user instead chooses the option to say that the phrasal clitic is written as a separate word, then even more questions appear.

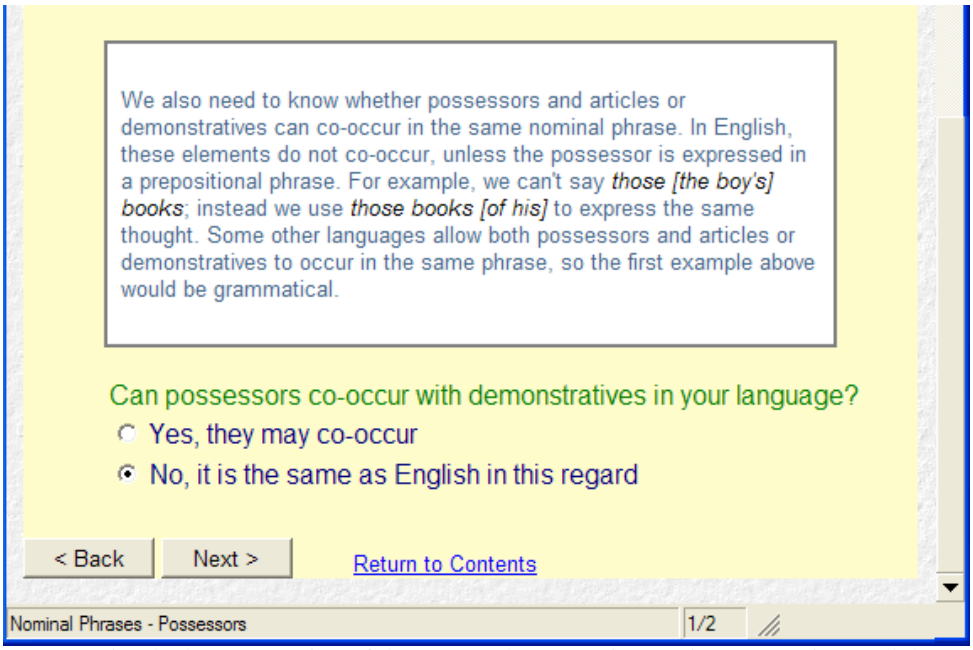

FIGURE 5.: The bottom portion of the page. It has some instruction, a question, and then two buttons, one for going back to the previous page and the other for going forward to the next page. It also has a link to jump to the main contents page.

3.2 Grammar draft to edit As the user works his/her way through these interactive pages, s/he can save their work and return later for another session. Whenever the work is saved, the output is produced based on the answers given so far. Naturally, we recommend that the user not look at the generated output until s/he has completed all the interactive pages.

Depending on the complexity of the language and how much data is entered, the draft of the practical grammar which is output could be about 60-90 pages if printed out. This includes the prose description and tables and interlinear data.

To illustrate the coverage of the practical grammar, the table of contents for the initial output of one grammar is shown in Figure 6 [4]

Use of XLingPaper The practical grammar is output in XLingPaper format, which can then be edited as described in sections 3.2-3.2. Before discussing this, we give a brief sketch of the advantages of XLingPaper.

Linguistic documents are by nature complex and also have many conventions. Using WYSIWYG editors like Microsoft Word and Open Officer Writer "work" but are not very convenient. As Simons & Black (2009) point out, WYSIWYG editors are "second wave" technology. XLingPaper, on the other hand, uses "third wave" technology and is designed specifically for linguistic documents.

Linguists commonly face three obstacles in formatting papers. First, all examples are numbered in a paper. If during the writing process the author discovers a need to insert an example, then the numbering of all following examples and all references to those examples within the text need to be re-adjusted. This mechanical change can be both time-consuming and prone to error. Similarly, if the author decides to reorder some examples, then the numbering needs to be adjusted appropriately. XLingPaper provides an automatic way to facilitate such numbering and renumbering.

Secondly, linguists cite the work of other researchers using a standard citation format. This format functions essentially as an abbreviation or reference to the full citation entry which appears in the references section of the paper. The burden of maintaining consistency between citation and reference typically falls totally on the author. Many a reader has been disappointed to find a citation to a paper in the body of a paper for which there is no entry in the references section. XLingPaper provides an automatic means for a writer to maintain consistency; all citations in the text must have a corresponding entry in the references. Conversely, XLingPaper will include only those entries in the references section which are cited in the text. This latter characteristic implies that one can maintain one master list of references and merely include it in any given paper. Only those references actually cited in the given paper will appear in the references section.

Thirdly, linguists commonly use a set of abbreviations while glossing examples. They usually include either a list of the abbreviations and their definitions in a footnote, in a special front-matter page, or in a back-matter page. As for citations and references, the burden of maintaining consistency between the abbreviations used in the text and the abbreviations defined in the list typically falls totally on the author. Many a reader has been disappointed to find an abbreviation in a gloss for which there is no corresponding entry in the list of ab-

[4] In addition to the first and second level sections shown in (6), there are twenty four third level sections.

Contents

FIGURE 6.: Table of contents for the initial output of one grammar

breviations. XLingPaper provides an automatic means for a writer to maintain consistency; the author can make it so all abbreviations in the text must have a corresponding entry in the list of abbreviations. Conversely, XLingPaper will include only those abbreviations in the list of abbreviations which are actually used in the text. This latter characteristic implies that one can maintain one master list of abbreviations[5] and merely include it in any given paper. Only those abbreviations actually cited in the given paper will appear in the list of abbreviations. By the way, XLingPaper also creates a hyperlink between the abbreviation in the text and the abbreviation in the list of abbreviations. Thus, a reader can click on the abbreviation and see what it means.

Furthermore, XLingPaper uses actionable data by marking-up linguistic documents in XML so one can produce multiple outputs from a single input. As a brief example, the short section shown in Figure 7 is how a portion of one XLingPaper document appears in the XMLmind XML Editor.

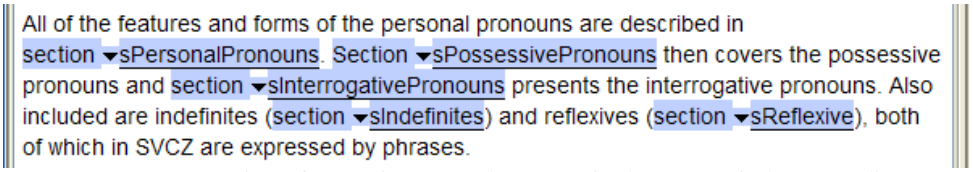

FIGURE 7.: A portion of an XLingPaper document in the XMLmind XML Editor

When this portion is formatted using the default PDF output format of XLingPaper, it looks like what is given in Figure 8.

All of the features and forms of the personal pronouns are described in section 2. Section 3 then covers the possessive pronouns and section 4 presents the interrogative pronouns. Also included are indefinites (section 5) and reflexives (section 6), both of which in SVCZ are expressed by phrases.

FIGURE 8.: Formatted pdf-output of the example in Figure 7

When this sample document is associated with a publisher style sheet designed for submissions to the *International Journal of American Linguistics* (see International Journal of American Linguistics (2011)), this portion will be formatted as in Figure 9. Notice that it is double-spaced and that the section numbers are in bold.

[5] The starter master list which comes with XLingPaper is based on the Leipzig conventions given in http://www.eva.mpg.de/lingua/resources/glossing-rules.php.

All of the features and forms of the personal pronouns are described in section **2**. Section **3** then covers the possessive pronouns and section **4** presents the interrogative pronouns. Also included are indefinites (section **5**) and reflexives (section **6**), both of which in SVCZ are expressed by phrases.

FIGURE 9.: Pdf-output of the example in Figure 7 formatted for *IJAL*

When this sample document is associated with a publisher style sheet designed for the journal *Language* (see Linguistic Society of America (2011)), this portion will be formatted as in Figure 10. Notice that it is single-spaced in a smaller font size, the section numbers are in regular type face, and that rather than using the word "section," it uses the section symbol §.

All of the features and forms of the personal pronouns are described in §2. §3 then covers the possessive pronouns and §4 presents the interrogative pronouns. Also included are indefinites (§5) and reflexives (§6), both of which in SVCZ are expressed by phrases.

FIGURE 10.: Pdf-output of the example in Figure 7 formatted for *Language*

The three different outputs shown in Figures 8-10 are all produced without any changes to the main content of the XLingPaper document. This shows the power of using actionable data.[6]

XLingPaper works natively on Windows, Mac OS X, and Linux operating systems.[7] An XLingPaper document can be output in any of five formats:

- Web page (html)
- PDF (via XeLaTeX; see http://scripts.sil.org/cms/scripts/page.php?site_id=nrsi&id=xetex)
- PDF (via RenderX; see http://www.renderx.com/)
- Microsoft Word 2003
- Open Office Writer

Those who have used XLingPaper have said things like the following quotes:

- "I'm totally hooked on this program now and am generally getting quite comfortable using it."

[6] For more on this, see the demonstration movie "The Power of Actionable Data" on the XLingPaper web site, http://www.xlingpaper.org/?page_id=14.

[7] This is largely due to the fact that the XMLmind XML Editor runs natively on these operating systems.

- It "has enabled me to be vastly more productive in writing linguistic papers and in dialoguing with linguistic consultants."
- "I really like using XLingPaper. It's a much better working space for me than MS Word (partly because I have spent so much time not being productive, in Word, and because of the intimidation of the blank page.)"
- "XLingPaper has been working great, and I've been using it to author ... most of what I write."

To see some sample papers produced via XLingPaper, see Working Papers # 1, 3, 4, 7, 8, 9, 10, and 13 at http://www.sil.org/mexico/workpapers/WPindex.htm.

While XLingPaper is a powerful authoring tool for linguistic documents, the user of PAWS does not have to learn everything about XLingPaper before s/he can begin editing. This is because PAWS already formats the sections, interlinear examples, and tables so that the user only has to key in the glosses or other additional information requested. Further, adding additional description or interlinear examples or tables can be done by simply copying and pasting similar ones already in the document.

XLingPaper outputs As we just mentioned, the output is in XLingPaper format, which allows editing within XML editors, and produces outputs in both HTML (World Wide Web Consortium (1998) and PDF (International Organization for Standardization (2005) formats. PAWS automatically generates the HTML output for the user's convenience.

The HTML output page corresponding to the input page from Figures 1-5 is shown in Figure 11.

While PAWS only generates the HTML output, XLingPaper allows for multiple possible PDF outputs.

XMLmind XML Editor We have found that using XLingPaper with the XMLmind XML Editor is the most convenient.[8] This is because the XMLmind XML Editor hides the XML from the user. In addition, the XLingPaper configuration files for the XMLmind XML Editor provide many other capabilities that makes it convenient for the author.

What the user sees within the XMLmind XML Editor for the first part of the same page we illustrated above in Figures 1-5 is given in Figure 12.

[8] See http://www.xmlmind.com/xmleditor/ for more on this exceptional structured editor.

7.3 Possessors

Possession can normally be expressed by a possessive pronoun (as seen in section 5.3), by a simple noun, or by a full nominal phrase. However, Spanish only allows possessive pronouns in the possessor position before the noun, with all noun and full nominal phrase possessors expressed in a prepositional phrase with *de* after the noun.

Within the languages which express possessors by nouns or full nominal phrases as well as by possessive pronouns, many also add some kind of marking, such as the *'s* in English, as an indication of possession. These markings are either affixes (or clitics) on the head noun or phrase-level clitics which attach to one end of the whole phrase. The English marking is this second type, because alongside phrases where the *'s* appears to attach to the head noun, as in *the boy's mother*, there are phrases which clearly show that the clitic attaches to the end of the whole nominal phrase, such as *the boy that I just talked to's mother* or *the girl in green's wonderful speech*. These examples show that possessors can include prepositional phrases and relative clauses. Possessors can also be embedded in one another, as in *the boy's sister's dog*. This is allowed in Spanish within the prepositional phrase after the noun.

Examples of possessed nominal phrases with simple and embedded possessors in Ayautla include:

(47) a. ni'yare chingabiu.
ENTER WORD GLOSS HERE
IMP.enter morpheme gloss-PL here
ENTER FREE TRANSLATION HERE.

b. ton xi tjinre ki'ndire xuta.
ENTER WORD GLOSS HERE
IMP.enter morpheme gloss-PL here
ENTER FREE TRANSLATION HERE.

Examples with prepositional phrases within the possessor include:

(48) a. 'enre na'ndi xi baja najñu xi suse kun.
ENTER WORD GLOSS HERE
IMP.enter morpheme gloss-PL here
ENTER FREE TRANSLATION HERE.

Examples with relative clauses within the possessor, included in simple full sentences are:

(49) a. ton xi tjinre ki'ndire xuta.
ENTER WORD GLOSS HERE
IMP.enter morpheme gloss-PL here
ENTER FREE TRANSLATION HERE.

...

As seen in the examples above, Ayautla marks the head noun within the possessor with an affix to distinguish possessors from any other nominal phrase.

The possessor (especially the possessive pronoun form, if Ayautla is like Spanish) occurs after the noun being possessed.

In English, possessors and articles or demonstratives do not co-occur in the same nominal phrase, unless the possessor is expressed in a prepositional phrase. For example, *those [the boy's] books* is ungrammatical; instead one would use *those books [of his]* to express the same thought. Some languages allow both possessors and articles or demonstratives to occur in the same phrase, so the first example above would be grammatical.

In Ayautla, nominal possessors may not occur in the same phrase as demonstratives.

FIGURE 11.: HTML output of the content of Figures 1-5

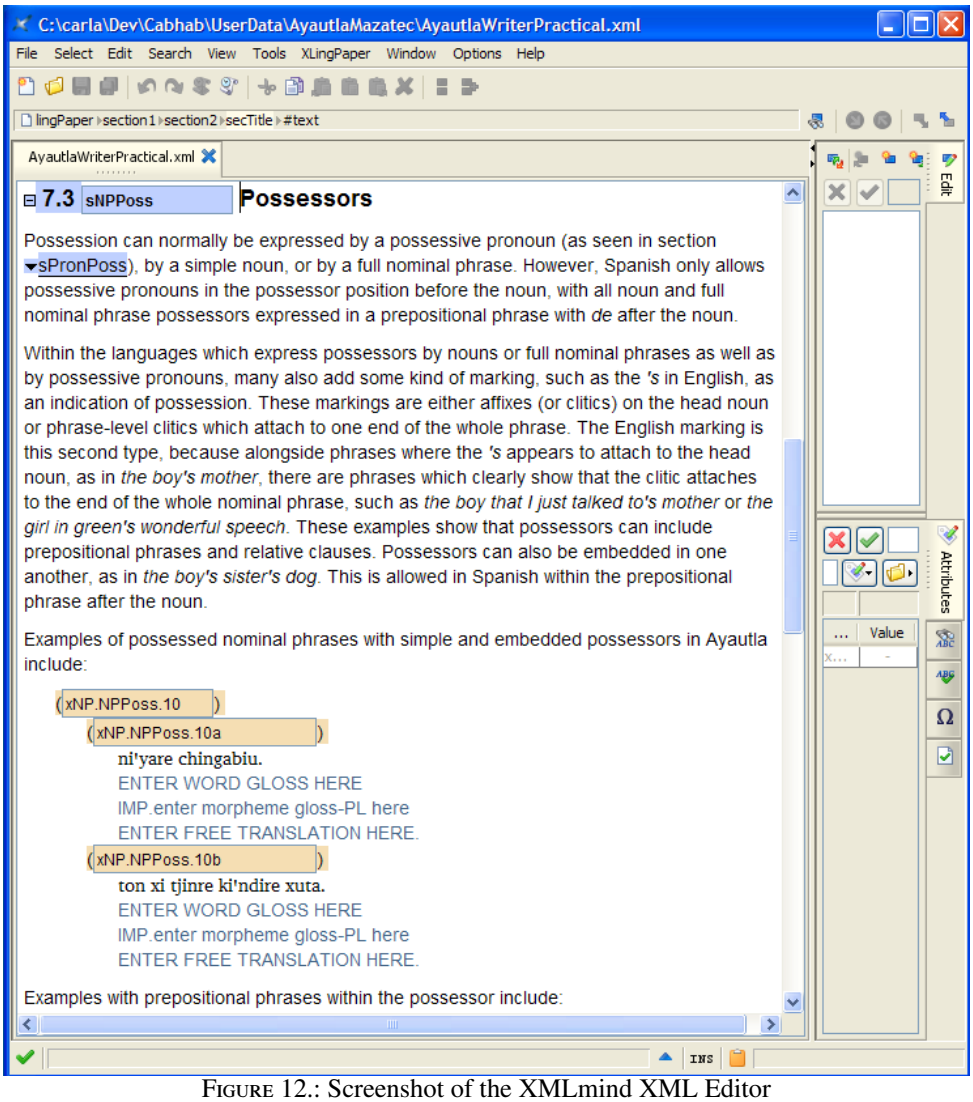

FIGURE 12.: Screenshot of the XMLmind XML Editor

The section level 2 item begins the portion, followed by several paragraphs of descriptive prose. It ends with two sets of interlinear examples. These have the four lines discussed in section 2.1. The editor allows the user to type in the information asked for in blue, as well as to add additional data and/or prose as appropriate.

4 How it works Having described what PAWS entails, we turn now to describing how it works.

4.1 The configuration files The PAWS program consists of a shell or host program (called cabhab) which has an embedded web browser and also processes a set of configuration files. These files determine the user interface such as menu items, define sets of transforms to apply to the answer file, and also determine what shows in the embedded web browser.

There are several sets of configuration files.

Controlling the shell There is a configuration file that controls what the cabhab shell shows the user and also how the answer file is transformed into various outputs.

For example, the menu items are defined as shown in (3).

(3)
```
<menubar>
   <menu id="File" label="File">
      <item command="CmdNewLanguage" defaultVisible="true"/>
      <item command="CmdOpenLanguage"/>
      <item command="CmdCloseLanguage"/>
      <item command="CmdSaveLanguageAs"/>
      <item label="-"/>
      <item command="CmdGenerateFiles"/>
      <item label="-"/>
      <item command="CmdLanguageFileLocations"/>
      <item label="-"/>
      <item command="CmdExit"/>
   </menu>
   <menu id="Edit" label="Edit">
      <item command="CmdCut"/>
      <item command="CmdCopy"/>
      <item command="CmdPaste"/>
      <include path="Extensions/*/MainConfigurationExtension.xml"
        query="root/menuAddOn/menu[@id='Edit']/*"/>
   </menu>
   <menu id="Language" label="Language">
      <item command="CmdLanguageProperties"/>
      <item command="CmdLanguageFileLocations"/>
      <include path="Extensions/*/MainConfigurationExtension.xml"
        query="root/menuAddOn/menu[@id='Edit']/*"/>
   </menu>
   <menu id="View" label="View">
```

```
            <item label="Show Toolbar" boolProperty="ShowToolbar"
                  command="CmdShowToolbar"/>
            <item label="Show Status Bar" boolProperty="ShowStatusBar"
                  command="CmdShowStatusBar"/>
            <item label="-"/>
            <item command="CmdBack"/>
            <item command="CmdForward"/>
            <item command="CmdRefresh"/>
         </menu>
         <menu id="Help" label="Help">
            <item id="Resources" command="CmdResources"/>
            <item label="-"/>
            <item id="About" command="CmdAbout"/>
         </menu>
      </menubar>
```

The commands referred to by <item> elements are defined in the configuration file as given in example (4).

(4)
```
<commands>
   <command id="CmdNewLanguage" label="Create _New
            Language" shortcut="Ctrl+N"
            message="NewLanguage" icon="New"/>
   <command id="CmdOpenLanguage" label="Open Language"
            message="OpenLanguage" shortcut="Ctrl+O"
            icon="Open"/>
   <command id="CmdCloseLanguage" label="Close Language"
            message="CloseLanguage"/>
   <command id="CmdGenerateFiles" label="Generate Files"
            message="GenerateFiles" shortcut="Ctrl+S"
            icon="Save"/>
   <command id="CmdSaveLanguageAs" label="Save Language
            As" message="SaveLanguageAs"/>
   <command id="CmdExit" label="E_xit"
            message="ExitApplication"/>
   <command id="CmdCopy" label="Copy" message="EditCopy"
            icon="Copy" shortcut="Ctrl+C"/>
   <command id="CmdCut" label="Cu_t" message="EditCut"
            icon="Cut" shortcut="Ctrl+X"/>
   <command id="CmdPaste" label="Paste" message="EditPaste"
            icon="Paste" shortcut="Ctrl+V"/>
   <command id="CmdLanguageProperties" label="Properties"
            message="LanguageProperties"/>
   <command id="CmdLanguageFileLocations" label="File _Locations"
            message="LanguageFileLocations"/>
   <command id="CmdBack" label="Back" message="BrowserBack"
```

```
            icon="Back" shortcut="Alt+Left"/>
      <command id="CmdForward" label="Forward" message="BrowserForward"
            icon="Forward" shortcut="Alt+Right"/>
      <command id="CmdRefresh" label="Refresh" message="BrowserRefresh"
            icon="Refresh" shortcut="F5"/>
      <command id="CmdAbout" label="About PAWS" message="AboutPage"/>
      <command id="CmdResources" label="Resources"
            message="ResourcesPage"/>
      <command id="CmdShowToolbar" label="Show Toolbar"
            message="ShowToolbar"/>
      <command id="CmdShowStatusBar" label="Show Status Bar"
            message="ShowStatusBar"/>
   </commands>
```

The message attribute refers to code in the cabhab program which is run when that command is invoked.

The set of transforms which are used to produce the various outputs are defined as illustrated in example (5). Only the one for the practical grammar output (in English) is shown. The others are similar.

(5)

```
   <answerFileTransformSets>
      ...
      <answerFileTransformSet>
         <transform
           file="Transforms/PAWSSKMasterWriterPracticalMapper.xsl"
           resultFileFromAnswerFile="//language/writerPracticalFile"
           ext="xml" saveResult="true"
           applyTransformWhenXPath=
               "/paws/\@outputWriterPractical[.='True']"
           insertConfigPathInTransformDOCTYPE="true"
           replaceDOCTYPE="&lt;!DOCTYPE
           lingPaper PUBLIC &quot;-//XMLmind//DTD XLingPap//EN&quot;
           &quot;XLingPap.dtd&quot;&gt;" lang="en">
            <xsltParameters>
               <param name="prmSDateTime" value="fake"/>
               <param name="prmSVersionNumber" value="fake"/>
            </xsltParameters>
         </transform>
         <transform file="Transforms/XLingPap1.xsl"
           resultFileFromAnswerFile="//language/writerPracticalFile"
           ext="htm"
           applyTransformWhenXPath=
               "/paws/@outputWriterPractical[.='True']"/>
      </answerFileTransformSet>
      ...
```

```
</answerFileTransformSets>
```

WEB PAGE DESCRIPTION The second set of configuration files are the web page descriptions. The development of each web page used in PAWS was done by a non-programmer linguist, who wrote XML files describing the content of the page. Example (6) shows a portion of the XML description used to produce the page shown in Figures 1-5.

(6)
```
<page id="NPPossessors" count="1/2">
   <title level="2">Nominal Phrases - Possessors</title>
   <introduction>
      The next type of modifier to consider is
      possessors. Possession can normally be expressed by a
      possessive pronoun (to be addressed in <section
      number="7">Pronouns</section>) or by a simple noun...
      a prepositional phrase with <example>de</example>
      after the noun.<br/>... These examples show that
      possessors can include pre/post-positional phrases
      and relative clauses.
    </introduction>
   <form section="np">
      <prompt>
        Think about how possession is expressed in your
        language. ...
      </prompt>
      <prompt>
        Key some examples with simple and embedded
        possessors here:
      </prompt>
      <textBox id="NPPossEmbeddedExample"
               dataItem="embeddedExample"/>
       <radioGroup>
         <groupName dataItem="possMarked" default="no">
          RNPPossMarked
         </groupName>
         <prompt>
            Based on your examples, does your language have
            any special marking to distinguish possessors
            from any other nominal phrase?
         </prompt>
         <radio id="NPPossMarkedNo" dataValue="no">
            No, there is no special marking
         </radio>
         <radio id="NPPossMarkedYesAffix" dataValue="yesAffix">
            Yes, the head noun within the possessor is
            syntactically marked via an affix
         </radio>
```

```
            <radio id="NPPossMarkedYesClitic" dataValue="yesClitic">
               Yes, the whole possessive phrase is syntactically
               marked via a phrasal clitic
             </radio>
            ...
         </radioGroup>
      </form>
   </page>
```

An XSLT transform then produces the web page itself on the fly while the user is running PAWS.

WRITER OUTPUT DESCRIPTION The next set of configuration files describes a given writer output.

The writer output was developed similarly: the linguist described the desired output in XML and then this XML was transformed into the XSLT that PAWS uses. For example, the portion of XML shown in (7) shows part of what ends up producing the kind of output given in Figure 11.[9]

(7)
```
<section2 id="sNPPoss">
   <secTitle>Possessors</secTitle>
   <p>
      <content>
          Possession can normally be expressed by a
          possessive pronoun (as seen in section
      </content>
      <sectionRef sec="sPronPoss"/>
      <content>
          ), by a simple noun, or by a full nominal
          phrase. However, Spanish only allows
          possessive pronouns in the possessor
          position before the noun, with all noun
          and full nominal phrase possessors expressed
          in a prepositional phrase with
      </content>
      <langData>de</langData>
      <content> after the noun.</content>
   </p>
   ...
   <p>
      <content>
          Examples of possessed nominal phrases with
```

[9] The use of the <content> element instead of plain PCDATA is a result of how the XSLT to transform this XML to XSLT was written: if one used PCDATA, the resulting XSLT would be incorrect.

```
        simple and embedded possessors in
    </content>
    <langName/>
    <content> include:</content>
</p>
<example>
    <interlinear exampleLoc="np/embeddedExample"/>
</example>
...
<p>
<content>As seen in the examples above, </content>
    <langName/>
<content/>
<case element="np" attr="possMarked">
    <caseText value="no">
        does not have any special marking to
        distinguish possessors from any other nominal
        phrase.
    </caseText>
    <caseText value="yesAffix">
        marks the head noun within the possessor with
        an affix to distinguish possessors from any
        other nominal phrase.
    </caseText>
    <caseText value="yesClitic">
        marks the whole possessive phrase with a phrasal
        clitic to distinguish possessors from any other
        nominal phrase.
    </caseText>
</case>
<content/>
```

4.2 PROCESS FOR PRODUCING WRITER OUTPUT The overall process for producing the writer output is illustrated in Figure 13.

The linguist writes several writer description XML files, each of which must conform to a Document Type Definition (also known as a DTD; see World Wide Web Consortium 2008). Each such file typically describes a section or a sub-section of the intended output. Each of these writer description files is then passed through an XSLT transform to produce the corresponding writer XSL file.[10] These are combined together in the master XSLT writer transform. The PAWS program then applies the answer file to this combined transform to produce the XLingPaper document output.

[10] This is done only once during the development process. The individual writer XSL files are then included in the installation package as part of PAWS.

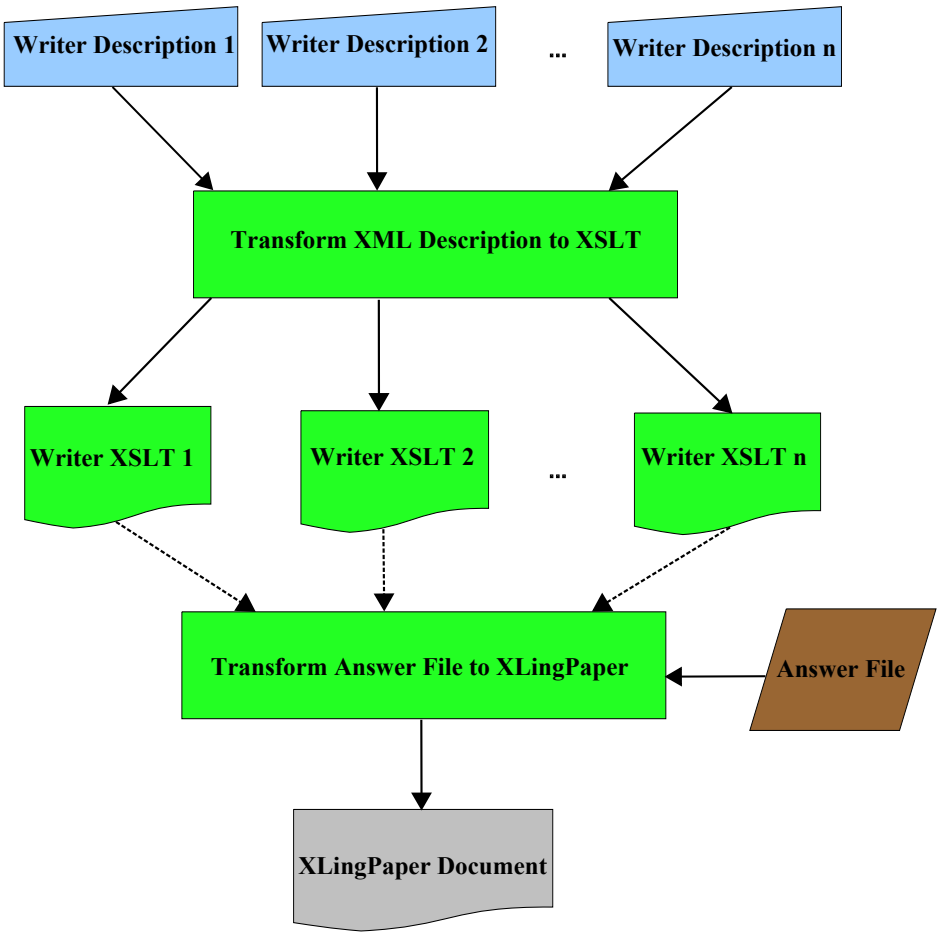

FIGURE 13.: Process of producing XLingPaper

4.3 Choice of outputs As noted above in section 3.1, through the use of actionable data, a single set of answers to questions and example data that the user enters can provide either a PC-PATR grammar file and test data for syntactic parsing or a choice of two styles of a grammar write-up.

This grammar write-up is an XML file in XLingPaper format, so it is ready for electronic publishing.[11] See examples in section 3.2 above.

4.4 Localization The original grammar write-up included in PAWS closely follows the order and style of the user interface pages within PAWS, so it is a descriptive, pedagogical grammar comparative to English. This has been customized with the addition of the option of producing a practical grammar style write-up. Currently, the practical grammar is available in English and in Spanish. The process of translating the practical grammar output involves making a new copy of the XML writer description files, such as the one shown in (7), and translating the text.

SIL International uses such practical grammars in Mexico, written in Spanish. (See Hollenbach (1999) as well as Pickett et al. (2001) and Persons et al. (2009) for examples.) Therefore, the practical grammar option has been translated into Spanish and the translation of the user interface is in process, to allow greater use throughout the Spanish-speaking world. Similar localization for other languages could be done in the future.

Additional customization is possible by the user (with configuration files to generate a transform), since PAWS employs XML technologies.

5 Conclusion This paper has shown how using XML technologies to produce an expert system allows PAWS to meet multiple needs and produce multiple outputs. While originally developed for syntactic parsing, it can also be used to produce practical grammars, with the more complex instructions hidden from the user. This practical grammar option, especially coupled with localization into the national language, allows linguistically-aware native speakers of indigenous languages to partner with linguists in the task of documenting and describing the minority languages of the world and providing useful grammars for each language community.

Workshops on grammar writing are much more productive by beginning with PAWS. In such workshops, the participants all complete PAWS and then are taught how to edit the output using XLingPaper. From then on, the workshop can move to dealing with any language-specific phenomena not covered in PAWS. The participants can be taught how to search for the needed data, how to analyze it and then how to write it up in the grammar.

Though the grammar drafts output by PAWS have a template-like quality, they are simply a big head start on writing the grammar. After editing and enhancing the grammar using XLingPaper, a unique description of the particular language can be produced.

[11] One reviewer of an earlier version of this paper mentioned the Mukurtu repository system (see http://www.mukurtu.org/). One could easily put the output of the edited XLingPaper result of PAWS on such a site. Another reviewer noted that a wiki rather than XML would be a possible target for a language community. We acknowledge this possibility with thanks. Since XLingPaper data is actionable, it is at least conceivable that one could create an XSLT transform that would convert the XLingPaper XML document to wiki pages. One could then post these pages to a wiki site, enabling the language community to refine the result.

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http://hdl.handle.net/10125/4533
http://nflrc.hawaii.edu/ldc/sp04

From corpus to grammar: how DOBES corpora can be exploited for descriptive linguistics

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The principles and techniques of language documentation developed during the last one and half decades and the sheer amount of corpora which have been compiled for endangered languages up to now will have an impact on grammar writing in particular with respect to the data base of grammars. On the other hand, advances in computer technology allow a closer link between corpus data which are the basis for generalizations and the grammatical description itself. The future the grammatical description of a language will not only present selected illustrative examples, but will also be linked to the entire set of corpus data that are the empirical basis for it. This makes generalizations transparent to the reader and open to falsification by the scientific community.

The article critically examines the relations between the DOBES corpus, the analysis and the grammatical description itself. Special attention will be laid on the particular the two fundamental perspectives of a semasiological and an onomasiological grammar, can be translated into the various kinds of search and concordancing routines to be executed in the corpus analysis. We present a typology of searches descriptive linguists need to apply. This typology defines requirements with regard to the functionality of specific software to be developed. In the second part, the article presents a technical solution, a preliminary version of a database/concordancing software specifically designed to fulfill the functions and principles outlined in the preceding sections.

1 Introduction Right now, there are about 50 DOBES projects documenting endangered languages around the world (cf. the DOBES map below).

Language documentation is a multi-purpose enterprise, but one important purpose of DOBES corpora is to serve as data bases for grammatical descriptions of these languages. Since these corpora have a different structure and different properties than the large monolingual corpora that are available for English, German and other major European languages they allow for and require different corpus linguistic methods. Or, to put it the other way round, corpus linguistic methods have to be adapted to the specific properties of DOBES corpora.

One of the great advantages of DOBES corpora over these traditional corpora is that they are always bilingual with an idiomatic translation in one of the main European languages, and in addition, that they often include a morpheme-by-morpheme glossing. This means

FIGURE 1.: The DOBES documentation projects http://www.mpi.nl/dobes

that DOBES corpora contain much more additional information in form of these types of annotations than traditional corpora. The large monolingual corpora mostly consist of plain text only. It is the overall goal of this article to show how corpora such as DOBES corpora can be exploited by corpus linguistic means in order to extract the kind of data that are necessary for grammatical descriptions.

What kind of data is necessary for a grammatical description can be deduced from the principles and requirements of grammaticography. One important distinction that is maintained in grammaticography is the one between a semasiological and an onomasiological approach to grammar.

The semasiological approach takes the formal expressions of a language as starting point and tries to find out what they mean in different contexts. This approach resembles the analytic tasks hearers have to fulfill in interpreting speakers' utterances. They have to start from the uttered expression and have to assign a meaning to them which is appropriate in the given shared context of the utterance.

The onomasiological approach, on the other hand, takes the meaning/ function as starting point and tries to find out which forms in a language may be used to express them. This approach resembles the generative task the speaker has to fulfill in order to form an utterance. The speaker has a concept of what he/she wants to communicate to the hearer and his/her task is to find the appropriate expression in a given shared context that fulfills the intended meaning best.

These different but complementary approaches to grammar have also an impact on the data searching methods to be applied to the corpus. The semasiological approach dominates in traditional computational treatments of monolingual text corpora. Specific lexical or grammatical forms in the target language are searched for in digital corpora. The goal is to

collect all different contexts in which these forms appear in order to find out the conventional meanings of these forms and their variation in different contexts.

The onomasiological approach, on the other hand, requires a semantic annotation such that all forms and constructions that express a certain semantic notion – for instance possession – are annotated in a way that the search for the annotation "possession" gives all different expressions of this notion. A semantic annotation is – of course - the rare exception in digital corpora, since they have to be added manually, which is a quite time-consuming process.

It is one of the main goals of this paper to show that the particular strength of DOBES corpora is that they can be exploited much more systematically than traditional monolingual corpora. They allow for searches that provide the necessary data for both the semasiological and the onomasiological approach in direct and indirect ways. The second goal of this paper is to present a linguistic database and concordancing software – the Poio Analyzer - that allows easily - i.e. in a user friendly manner – to conduct the text searches that are necessary to extract the kinds of data from a DOBES corpus that are required for the two different analytical approaches to grammar just mentioned.

The structure of the paper is as follows. The main properties of DOBES corpora and their implications for the various search types will be dealt with in Section 2. Section 3 presents a general typology of possible search types within DOBES corpora. These search types are – in principle – independent of the two approaches to grammar and the types of data they require. It will be demonstrated that these kinds of searches exceed the possibilities that monolingual corpora allow for. In Section 4, it will be exemplified how these search types can be utilized to gain data that are relevant for a semasiological description. In Section 5 in turn, it will be exemplified how data may be extracted from a DOBES corpus - using these search types - that are relevant for the onomasiological description. In Section 6 and Section 8, the functionality and the shortcomings of Elan with regard to concordances will be evaluated and the prototype of a linguistic database and concordancing software – the Poio Analyzer - will be introduced that is designed specifically for the needs of a descriptive linguist.

2 The structure and properties of DOBES corpora The typical structure of an annotated text of a DOBES corpus can be seen in Figure 2. An annotated text consists minimally: a) of a text tier (abbreviated *tx* in Figure 2) containing the transcribed text of the audio and video recording, and b) a free idiomatic translation tier (abbreviated *ft* in Figure 2). Many DOBES corpora have, in addition, a morpheme-by-morpheme glossing such that there is c) a tier with a morpheme segmentation (abbreviated *mo* in Figure 2) and d) a tier with lexical and grammatical glosses corresponding to the segmented morphemes in the *mo* tier (abbreviated *gl* in Figure 2).

The tx tier contains the usually time-aligned transcription of the audio/video recording. These transcriptions are usually not based on the IPA, but on an already existing conventional orthography, or on a practical orthography developed by the documentation team. Associated with the tx tier there is a ft tier which contains the free or idiomatic translation of the target language text. The language used for the free translation is usually one of the major European languages often the one that replaces the endangered language in the community. In the example in Figure 2, this is English. Many documentation teams enriched the

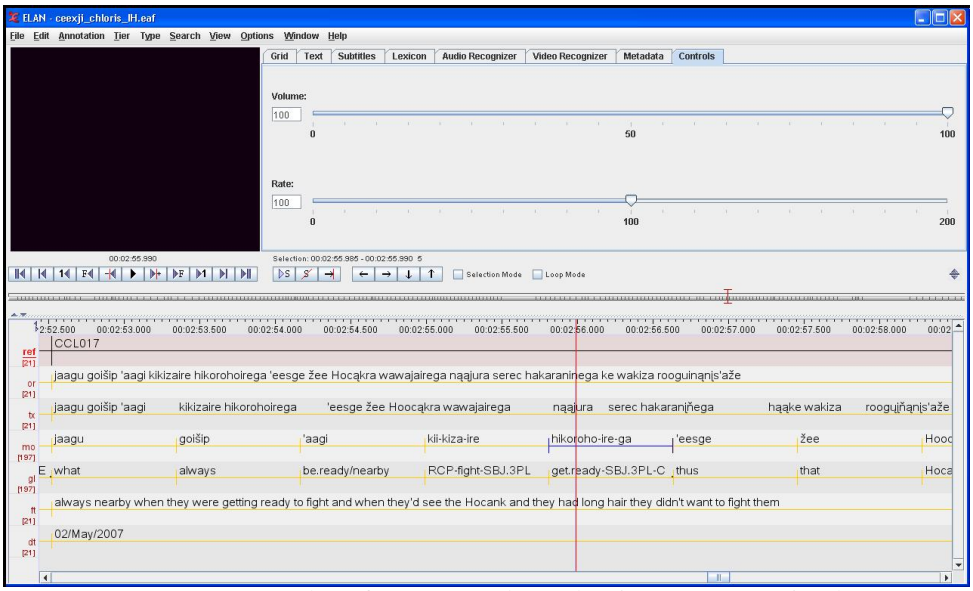


FIGURE 2.: Screen shot of an annotated Hocąk (Siouan) sentence in Elan

transcription in the tx tier and its translation in the ft tier with a second type of translation called lexical and grammatical morpheme-by-morpheme glossing. For this, a morpheme segmentation in the mo tier is matched with a gl tier that contains the lexical or grammatical glosses; cf. Figure 2.

It has to be kept in mind that these four essential parts of an annotated text involve previous and preliminary decisions on the side of the linguist that may turn out to be wrong later on in the process of the advancing documentation.

(1) With regard to the text tier (tx):

1. The practical orthography developed by the documentation team may be based on a wrong phonological analysis;
2. The segmentation of the text in sentence/ utterance units may turn out to be wrong later on;
3. The segmentation of the text into words may turn out to be wrong later on;

(2) With regard to the translation tier (ft):

1. The free translation into the European language may be semantically incomplete (i.e. certain forms of the target language are not translated and are left to inference) or may contain semantic elements that are only implied in the text of the target language but are obligatory in the mediating language;

(3) With regard to the morpheme and gloss tiers (mo/gl):

1. The identification of the grammatical and lexical morphemes and their status may turn out to be wrong later on;
2. Or, the assignment of grammatical function/ lexical meaning to a lexical or grammatical form may be wrong or incomplete;

The main goal of the documentation of an endangered language is not the grammatical analysis of the language *per se*, but the collection and processing of a representative corpus of texts in a way that a non-speaker can access it. It is hence obvious that the list of grammatical forms and lexical items has to be preliminary in the documentation process itself. However, even if there are mistakes in the transcriptions, in the translations, and in the morpheme-by-morpheme glossing, all three elements of the annotation represent an invaluable source of additional information that can be exploited in corpus linguistic searches. DOBES corpora are parallel corpora relating a morpheme-by-morpheme translation as well as a free translation to the text of the target language. This kind of additional information presupposes a preliminary phonological analysis (with regard to the transcription) as well as a preliminary grammatical analysis (with regard to the glossing). It will be shown in a moment that digital corpora of this DOBES type allow types of searches that are interesting for descriptive purposes and that go beyond the possibilities of traditional monolingual corpora. These additional search possibilities will be systematically explored in the following section.

3 A TYPOLOGY OF CORPUS LINGUISTIC SEARCHES IN DOBES CORPORA From a technical point of view the search types a descriptive linguist would like to apply to a DOBES corpus are independent of the distinction between the two basic approaches to grammar mentioned above. The most important search types are summarized in Search for a single lexical or grammatical form F1 or a single construction C1 consisting of more than one element in a single tier x1 within a linguistic context defined by the level of syntagmatic complexity/ grammatical level: and Search for the co-occurrence of two or more lexical or grammatical forms F1 and F2, or of construction C1 and C2 in one specific tier x1 or across different tiers x1-n within a linguistic context defined by the level of syntagmatic complexity/ grammatical level:.

(4) • Search for a single lexical or grammatical form F_1 or a single construction C_1 consisting of more than one element in a single tier x_1 within a linguistic context defined by the level of syntagmatic complexity/ grammatical level:

a) tier x_1 $[...F_1...]_{word}$ $[...C_1\text{-}C_1...]_{word}$

b) tier x_1 $[...F_1...]_{phrase}$ $[...C_1\text{-}C_1...]_{phrase}$

c) tier x_1 $[...F_1...]_{clause/sentence}$ $[...C_1\text{-}C_1...]_{clause/sentence}$

Comments:

- Forms or constructions may be searched within all kinds of tiers, i.e. tier x_1 = {tx, mo, gl, ft, ...}

- F_1 stands for a string of characters that does not exceed the word boundary, e.g. a submorpheme, a morpheme, a word, a lexical or grammatical gloss, a word of the language of translation, etc.}
- C_1 stands for any discontinuous chain of linguistic units with a conventionalized meaning within a certain level of syntagmatic complexity, for instance circumfixes on the word level, or analytic constructions such as the *will* + $Verb_{INF}$ future construction in English;

The Search results should be presented in an interlinear version. It should be possible to store the search results/ hits as a separate data set which may be the basis for another search. It should be possible that the context size of the concordances can be determined with respect to the different levels of syntagmatic complexity (see below Table 1).

Search for the co-occurrence of two or more lexical or grammatical forms F_1 and F_2, or of construction C_1 and C_2 in one specific tier x_1 or across different tiers $x_{1\text{-}n}$ within a linguistic context defined by the level of syntagmatic complexity/ grammatical level:

a) tier x_1 $[...F_1/C_1\text{-}C_1...F_2/C_2\text{-}C_2...]_{\text{word/ phrase/ clause/ sentence}}$
Between the linguistic items (i.e. forms/ constructions) $F_{1\text{-}2}/C_{1\text{-}2}$ which are searched for in this search type – on a single tier x_1 - a logical operation can be defined such F_1 {AND, OR, AND NOT etc.} F_2, or F_1 {AND, OR, AND NOT etc.} $C_1\text{-}C_1$, and so forth.

b) tier x_1 $[...F_1/C_1\text{-}C_1...]$ word/ phrase/ clause/ sentence and tier x_2 $[...F_2/C_2\text{-}C_2...]$ word/ phrase/ clause/ sentence
Between the linguistic items F_1 in tier x_1 and F_2 in tier x_2 or C_1 in tier x_1 and C_2 in tier x_2, and so forth, which are searched for in this search type, a logical operation can be defined such that F_1 in tier $_1$ {AND, OR, AND NOT etc.} F_2 in tier x_2, or $C_1\text{-}C_1$ in tier x_1 {AND, OR, AND NOT etc.} $C_2\text{-}C_2$ in tier x_2, and so forth.

The principle types of corpus linguistic searches summarized in an abstract form in Search for a single lexical or grammatical form F1 or a single construction C1 consisting of more than one element in a single tier x1 within a linguistic context defined by the level of syntagmatic complexity/ grammatical level:-Search for the co-occurrence of two or more lexical or grammatical forms F1 and F2, or of construction C1 and C2 in one specific tier x1 or across different tiers x1-n within a linguistic context defined by the level of syntagmatic complexity/ grammatical level: will be applied to specific data needs of the two complementary approaches to grammar in the subsequent sections (cf. Sections 4 and 5). Different questions in a semasiological approach and an onomasiological approach will be posed and it will be show how these different questions could be translated into different kinds of searches. The illustrating examples come from the Hocąk corpus (Hartmann et al. 2009ff), a DOBES corpus compiled within the DOBES project "Documentation of the Hocąk Language" some years ago.[1]

[1] Cf. the website of the DOBES project "Documentation of the Hocąk Language" http://www2.uni-erfurt.de/sprachwissenschaft/Vgl_SW/Hocank/index_frames.html

grammatical units	**levels of syntagmatic complexity**
submorpheme	word
lexical and grammatical morphemes (stems and affixes) and their combinatory possibilities	word
lexical and grammatical words and their combinatory possibilities	phrase
phrase	clause
clause	(complex) sentence
sentence	text/ discourse

TABLE 1.: Grammatical units and the levels of complexity

4 STRUCTURAL GRAMMAR – THE SEMASIOLOGICAL APPROACH The goal of a structural grammar is to identify the lexical and grammatical units (including grammatical constructions), and to find out the syntagmatic possibilities of the combinations of these units on all syntagmatic levels of complexity. There are at least four such levels of complexity: the word, the phrase, the clause (or simple sentence), and the complex sentence, cf. Table 1.

On the word level, the descriptive linguist has to identify all lexical and grammatical morphemes of a language, their respective paradigms, and all rules of syntagmatic combinations of bound morphemes with lexical morphemes. This task implies among other things that word forms – the primary empirical basis of this task – have to be compared in order to find stem and affixes. This task is easier to solve if there is a preliminary analysis available in form of a morpheme-by-morpheme glossing.

On the phrase level, the descriptive linguist has to identify all lexical and grammatical words and their possible combinations in phrases. This task is easier to solve if there is a parts-of-speech annotation which, unfortunately, is lacking systematically in DOBES corpora.

And last but not least, on the level of the clause and complex sentence, the descriptive linguist has to determine all phrase types and their possible combinations in clauses and complex sentences. This task would be easier to solve, if there were a phrase structure annotation which is lacking in DOBES corpora as well.

One may say that the better or richer the annotations the easier are the problems of a structural grammar to solve. Whether a text corpus comprises a morpheme-by-morpheme glossing or not makes a big difference with regard to the formulation of searches in the text corpus and the exactness and relevance of the hits one gets out of these searches. The subsequent sections illustrate some corpus linguistic methods that can be applied to DOBES corpora in order to gain data that are relevant for a structural grammar and the semasiological approach to grammar. These illustrations remain on the word level. On the higher levels of syntagmatic complexity the lack of a parts of speech and phrase structure annotation in DOBES corpora complicates the application of corpus linguistic methods. The descriptive linguist has to find indirect searches in order to identify the syntactic units a language ahs above the word level.

xu̯nu̯ig 2	**xu̯nú̯**nąąkšąną 1	xu̯u̯nu̯igra 1
xu̯nu̯iga 1	**xu̯nu̯**nįįsge 1	xu̯u̯nu̯įk 3
xu̯nu̯igną 1	**xu̯nu̯**nį́k 1	xu̯u̯nu̯įkra 1
xu̯nú̯ignąągre 1	**xunu̯**xjį́ 1	xu̯u̯nu̯nąǩ 5
xu̯nu̯ignąągre 2	**xu̯nu̯**xjį 1	xu̯u̯nu̯nąka 1
xu̯nu̯igra 1	**xu̯nú̯**xjįnįk 1	Xu̯u̯nu̯nįkga 1
xu̯nu̯igšąną 1	Xurucre 2	xu̯u̯nú̯nįkjeega 1
xu̯nu̯ik 1	xusgajaną 1	xu̯u̯nu̯nįkra 1
xu̯nú̯ik 1	xuu 3	xu̯u̯nu̯xjį́ 1
xu̯nu̯ik 3	xu̯u̯nu̯ 3	xu̯u̯nuxjįgrašge 1
Xu̯nú̯ika 1	xu̯u̯nu̯įg 1	xú̯u̯nu̯xjįnįkra 1
xu̯nu̯ikra 2	xu̯u̯nu̯įgižą 1	xu̯u̯nu̯že 1
xu̯nú̯įkregi 1	xu̯u̯nu̯įgnąąka 2	
xu̯nu̯ną 1	xu̯u̯nú̯įgnąka 1	

TABLE 2.: Extract from the word list of the entire Hocąk corpus: *xu̯nu̯* 'small, little'

4.1 IDENTIFICATION OF LEXICAL UNITS Words - word forms to be more precise - can be identified in the transcription line (tx tier) by blanks at the left and the right edge. However, problematic cases arise for instance with clitics and compounds. The transcription team necessarily decided at some point in the documentation that a certain form is a clitic, or not, by using blanks. The problem is that this decision may be wrong or inconsistent throughout the corpus for various reasons (e.g. progress or changes in grammatical analysis during the transcription process, inconsistent analysis on the basis of different criteria, native speakers changing intuition etc.). Furthermore, the decision whether a combination of nouns is a coordination of phrases or a nominal compound may be difficult to draw, if there are no morphological markers that indicate this kind of relation; therefore the transcription may be inconsistent with regard to this question too.

The identification of lexical units requires that all forms of a lexeme (including stem allomorphs) and the lexeme itself are identified together with its conventional meaning (polysemy included). Homophonous forms should be found also. There are two possibilities with regard to a DOBES corpus, either the corpus has a morpheme-by-morpheme segmentation/glossing (cf. next subsection Section 4.1.1), or not (cf. Section 4.1.2).

4.1.1 IDENTIFICATION OF LEXICAL UNITS: WITHOUT MORPHEME SEGMENTATION AND GLOSSING IN THE CORPUS There are three possible strategies in order to identify lexical stems:

a) One may export all words of the target language (defined by blanks in the text corpus) and list them alphabetically. Words of the same form are simply counted; the stems of inflected or derived word forms can be found by comparison: the larger stem parts of the words are identical or at least similar. See Table 2 for an example of this procedure from the Hocąk corpus.

Table 2 contains a segment of all word forms of the Hocąk corpus alphabetically sorted. This wordlist was compiled and exported with Elan. The segment in Table 2 contains all word forms that resemble the lexeme *xu̯nu̯* 'small, little' in the corpus. As can be seen in this list, there are derived forms of *xu̯nu̯* 'small, little' with different suffixes, and there are

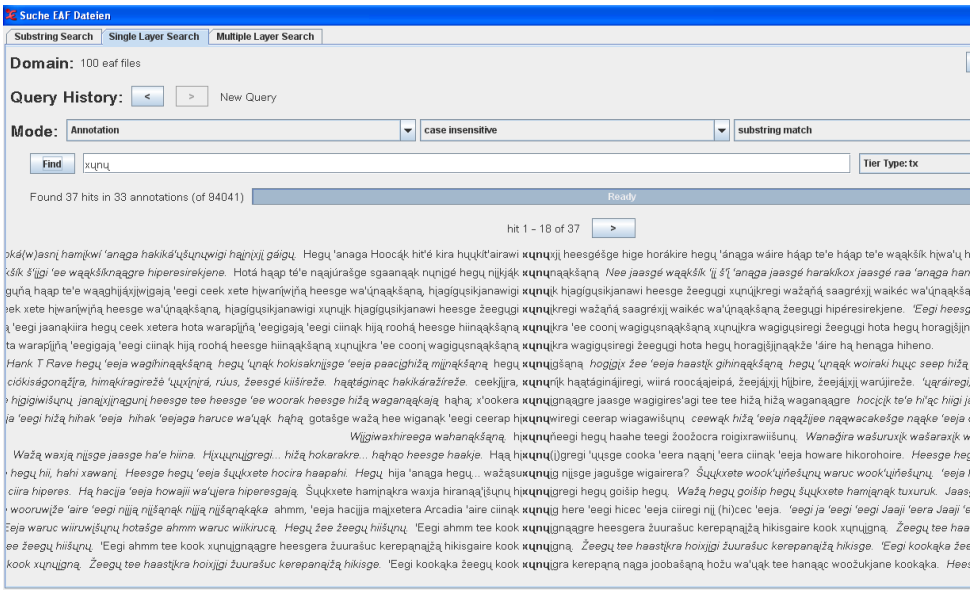


FIGURE 3.: Selected concordances of a search of *xu̧nu̧* 'small'

compounds of *xu̧nu̧* 'small, little' with other lexemes. In addition, it is obvious that there are inconsistent spellings of *xu̧nu̧* 'small, little', the forms in bold with short vowels, the forms in the last two columns with a long stem vowel. Nevertheless, this method allows identifying stems by means of comparison of the similar word forms and, in addition, it is possible to some degree to identify the allomorphs of the lexical morpheme. A problem arises with prefixed word forms. They appear in another segment of the alphabetical list of words, but see Figure 3 below. The list in Table 2 exhibits also a minor technical problem with Elan, the annotation software with which the word list was generated. Elan ignores the nasal /u̧/ vs non-nasal /u/ in the sort order, so that different words appear in the middle of the list (e.g. *xuu* 'leg'), it also ignores stressed vowels which is, however, helpful in this case.

b) The second strategy may be to search for strings which are hypothetically part of the word stems in the object language (using regular expressions, if necessary); for instance, if you search for *xu̧nu̧* 'small' in the tx tier of the corpus, you'll get 37 hits, among them also forms with prefixes as can be seen in the concordances in Figure 3 below. The advantage of this strategy is that you get prefixed and suffixes as well as compounded forms of the hypothetical stem. The disadvantage, however, is that spelling alternations and stem allomorphy is ignored.

c) The third strategy starts from the translation tier. One may search for a lexical item in the free translation ft tier assuming that there is a lexical match in the object language. For instance, if you search for *small/little* in the ft tier, you indeed get lexical matches in the target language, cf. (5), or you get forms with a diminutive marker (glossed DIM) as can be seen in (6).

(5) ref ED3024
tx cii xu̯u̯nu̯i̯k hižą ’u̯u̯
mo cii xu̯u̯nu̯-i̯k hižą ’u̯u̯
gl house be.small(OBJ.3SG)-DIM one do/make(SBJ.3SG)

tx jaagu nu̯i̯ hicec ’eeja
mo jaagu nu̯i̯ hicec
gl what water near
ft he made a small house by the river
dt 25/Oct/2004

(6) ref CTD003
tx žee ceek honu̯wąk ’eeja tee hocicigižą, nu̯i̯kjąk nąągre
mo žee ceek ho-nu̯wąk ’eeja tee hocicį-ig-ižą nu̯i̯kjąk nąągre
gl that first/new APPL.INESS-run there this **boy-DIM-one** child these
ft from the start, **a little boy**, these children...ahm...
dt 11/May/2006

In (5), the result of the search is the expected property word *xu̯u̯nu̯-i̯k* ’small-DIM’, however, with the diminutive marker *–(n)i̯k*; in (6), there is no lexical equivalent of the search item ’small’, instead one gets a noun with a diminutive marker only. This strategy has the advantage to provide an overview of the forms in the target language that correspond a specific form of the language of translation. It is hence a search type that rather belongs to the onomasiological approach. In addition, it allows the identification of the allomorphs of a morpheme. Another advantage is that this strategy allows the finding of lexical paradigms and stem suppletivism. The disadvantage is that this strategy ignores the polysemy (manifest as variation in the translation) of a form.

4.1.2 WITH MORPHEME-BY-MORPHEME GLOSSING IN THE CORPUS The identification of lexical stems is of course much easier, if there are morpheme breaks and a glossing of the lexical and grammatical morphemes. The morpheme-by-morpheme interlinear glossing presupposes an analysis of lexical and grammatical forms. The mo tier contains the underlying or standardized form of the grammatical and lexical morpheme, and the gl tier attributes the standard glossing (*Grundbedeutung*) of the morpheme. Searches of the lexical item on the mo tier allow finding the allomorphs of a lexical morpheme by comparing the hits with the corresponding form on the tx tier. For instance, in the Hocąk corpus, there are quite a few variously abbreviated forms of *anąga* ’and’ such as *-nąga* in the tx tier which could not be found otherwise. These forms are allomorphs of *anąga*.

4.2 IDENTIFICATION OF GRAMMATICAL UNITS The Identification of grammatical units requires the establishment of the morpheme-allomorph pairings and its grammatical meanings or functions. With respect to corpus linguistic searches in DOBES corpora, there are two possibilities: either the corpus has a morpheme-by-morpheme segmentation/glossing, or not.

4.2.1 Identification of grammatical units: without morpheme segmentation and glossing in the corpus The methods to be applied here are quite similar to the ones applied for the identification of lexical units, see above Section 4.1. The first strategy is to export all words of the target language (defined by blanks in the text corpus) and list them alphabetically. The inflected and derived word forms will show up in the list if the stems remain formally constant and have no prefixes. One has to look for systematic variations with regard to form-meaning pairings in the tx line and the ft line. If there are systematic form-meaning variations with respect to some affix-like form or with respect to some potential grammatical words, one can proceed with searching these forms in the text tx tier. For instance, in Hocąk, progressive aspect is systematically expressed by means of certain verb-auxiliary analytical constructions. Once the construction is discovered, one may search these constructions systematically on the tx tier.

Another strategy could start with prototypical nouns and verb, since grammatical variation can be expected to occur primarily with words of the open classes. These prototypical nouns and verbs have to be looked for in the translation ft tier. Under the assumption that for instance inflected verbs in the translation ft tier correspond to inflected verbs in the text tx tier, one may start with searches for prototypical verbs and nouns in the ft tier. This strategy can be applied also to grammatical meanings: grammatical meanings such as personal pronouns ('I', 'you', etc.), progressive aspects (e.g. 'V-*ing*'), and so forth can be searched for in the translation ft tier. The results can be compared with what corresponds to it in the tx line of the object language. The problem with this kind of search is that one will not find complete paradigms in the text corpus. Elicitation of forms with a native speaker is much more promising here as a strategy.

The latter strategy can be exemplified with an example from the Hocąk corpus. If one want to find out, if progressive aspect (PROG) is marked grammatically in Hocąk, one may search for *V-ing* constructions in the translation ft tier. Of course, the range of hits one gets is much wider than just the clear progressive uses of this form, since the *–ing* form in English is not restricted to progressive aspect. So, one has to select from the results of this search the cases which seem to be good cases of a progressive meaning in English and may compare this with the forms in the text tx tier.

A variation of this kind of search is to choose a specific probably frequent verb and search for its progressive construction in the translation tier. For example, a search for "was looking" receives 6 hits in the Hocąk corpus with quite interesting results. First of all, one gets the standard analytic construction in Hocąk for the expression of progressive aspect (cf. the text in bold in the second line of example (7) corresponding to the English meaning 'listening to them'); it is one possible verb auxiliary construction for progressive aspect; but one gets also an alternative expressions such as the reduplication (cf. first line in example (7) which corresponds to 'was looking'), and more astonishing, a construction with the habitual marker (glossed HAB) on the verb, cf. (8).

(7) ref TWI026

tx	*Hegų*	*hegų*	*han´ąąc*	*horoğóğoc*	*hegų*
mo	hegų	hegų	hanąąc	horo<ğo>ğoc	hegų
gl	that.way	that.way	all	<RDP:ITER>**look.at**(SBJ.3SG)	that.way

allomorphs	**grammatical meanings/functions**	**gloss**
-kje		
-kjane		
-kjene	future intentional, irrealis, desiderative, obligation	FUT
-kjąnąhe		
-kjenehe		

TABLE 3.: Allomorphs of the future tense marker *–kjene* FUT in the Hocąk corpus

tx *wan´ąxgų* *wa'ųąkšąnąhegų*
mo wa-nąąxgų wa'ų-'ąk-šąnąhegų
gl **OBJ.3PL-hear(SBJ.3SG) do/be-POS.HOR-DECL** that.way
ft It was looking all around and listening to them.
dt 21/Sep/2006

(8) ref HOR029
tx *Hotoğocnaga* *hegų* *šįįcrašge* *nąąsura...* *hoipįnį*
mo hotoğoc-nąga hegų šįįc-ra-šge nąąsu-ra hoipįnį
gl look.at\1E.A-and that.way rear-DEF-also head-DEF spin

tx *haakirinąk* *hegų* *hakjopahišge*
mo ha<ha>kirinąk hegų hakja-ho-hapahi-šge
gl <1E.A>land.on that.way back-APPL.INESS-go.toward-also

tx *hamįąnąknągašge,* *cąągeja* *gųągaira* *horoğocnįįsgešųnų.*
mo hamį<ha>nąk-nąga-šge cąąk-'eeja gųągaira horoğoc-nįįsge-šųnų
gl <1E.A>sit.on-and-also outside-there sometimes look.at-VAGUE-HAB

ft I got on it and spun around on it **glancing** outside once and a while, while I **was looking** over the back end.
dt 22/Sep/2006

Especially the latter result is due to the polysemy of the English progressive aspect on *–ing* which obviously can be used to express habitual meanings too. The latter type of search equally belongs to the onomasiological approach to grammar.

4.2.2 WITH A MORPHEME-BY-MORPHEME SEGMENTATION AND GLOSSING IN THE CORPUS If grammatical morphemes are already glossed, it is of course easy to find all its allomorphs and all its meanings. Just look for the grammatical gloss on the gloss tier. For instance, if one looks for the Hocąk future tense marker glossed FUT one finds at least five different forms (allomorphs) for this marker *–kjene* 'FUT', cf. Table 3.

The results of this search show that there is some allomorphy associated with this morpheme and, in addition, that this morpheme is actually polyfunctional. It marks future tense, but also different kinds of modal meanings such as 'should' and others.

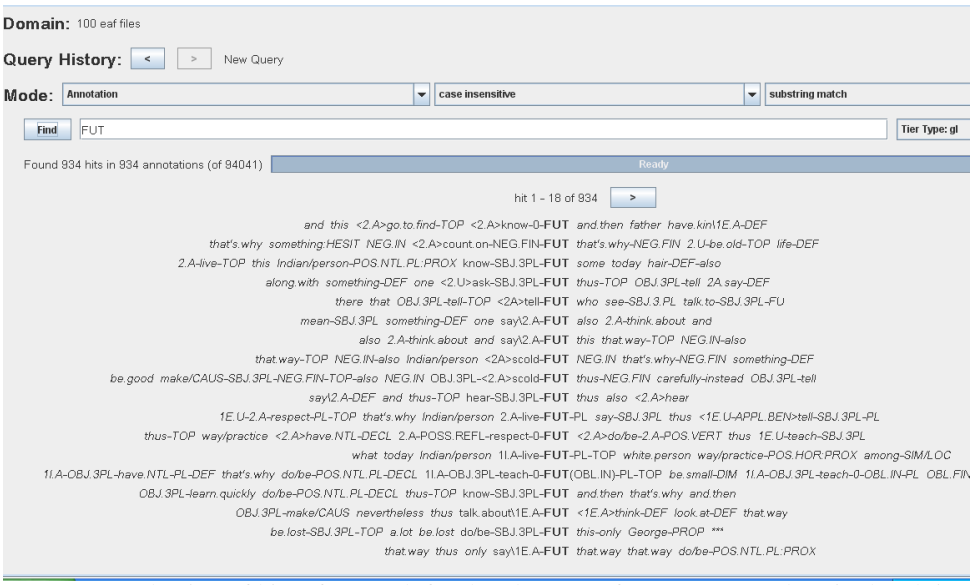


FIGURE 4.: Selection of hits of a search for the gloss FUT (future tense marker) in the gl tier

4.3 WORD INTERNAL MORPHOLOGICAL STRUCTURE – THE COMBINATION OF LEXICAL AND GRAMMATICAL MORPHEMES The task here is to find out the possible combinations of lexical and grammatical morphemes within the word; in case that clitics are involved the searches have to transcend the word boundary. This can be done in a DOBES corpus with an interlinear glossing simply by searching the grammatical item and analyzing the forms that appear to the left or to the right in the concordances. This search can be executed on the morpheme break mo tier or on the gloss gl tier. This kind of search can be illustrated with an example from Hocąk.

Hocąk verbs have quite complex chains of suffixes and enclitics which are all formally identified. However, the possible syntagmatic combinations are not known. In order to find this out, all kinds of combinations of grammatical suffixes/ enclitics [stem-X- ....-Y] with all kinds of morphemes in between have to be searched. Because of the morpheme glossing in this corpus, it is easy to find all syntagmatic combinations of the relevant grammatical formatives. It suffices to search for the gloss and then analyze the chains of suffixes/ enclitics. For instance, if one searches for the gloss FUT which is the gloss for the future tense marker *–kjene* 'FUT' and its allomorphs, one gets chains of glosses like the ones given in Figure 4. As can be seen already from this selection, the variety of grammatical formatives that may follow the FUT marker or that precede it is remarkable. In order to arrive at a kind of morphological template for the suffixes/ enclitics in Hocąk verbs, various combinations have to be searched for.

Another question would be: how to examine morphophonemic processes with corpus linguistic methods in DOBES corpora. Hocąk has heavy morphophonemic processes in the prefixes, i.e. the outcome of the combination of two prefixes often results in a very opaque form. See, for instance, *hųųroğoc* 'he was looking at me' which appears in example 9. The

underlying form is: *ho-į-Ø-roǧoc* with a divided stem *ho-roǧoc* 'look at' and the pronominal infixes 1SG.UG(me)-3SG.A(he).

(9) ref HOR068
tx *Hegų wogitekji* ***hųųroǧoc***
mo hegų woogitek-xjį **ho<į-Ø->roǧoc**
gl that.way be.angry-INTS **<1E.U-3SG.A>look.at**
tx *wa'ųąkšąną, hegų 'eeja nųųgiwąkjį*
mo wa'ų-'ąk-šąną hegų 'eeja nųųgiwąk-jį
gl do/be(SBJ.3SG)-POS.HOR-DECL that.way there run-INTS
tx *kirikere haa.*
mo kiri-kere haa
gl arrive.back.here-go.back.there make/CAUS\1E.A
ft He was looking at me real mad and I left there running fast.
dt 25/Sep/2006

What happens here is that the underlying pronominal affixes merge with the first part of the stem in quite unpredictable ways. The morphophonemic process can easily be examined by comparison of the gloss in the gl tier with the form in the text tx tier. In order to find out, whether this type of morphophonemic process happens regularly, one may search for the string *hųų* in the text tx tier to get all instances of this process. Unfortunately, this search gives also words that are not inflected in this way such as *hųųc* 'bear' and *hųųk* 'chief'**.** A solution would be to search across tiers, the form *hųų* itself in the tx line, and the function 1SG.UG-3SG.A in the gl tier, in order to avoid to get all words that begin with *hųų-*.

4.4 BEYOND THE WORD LEVEL Structural units beyond the word level of complexity comprise grammatical categories that are expressed analytically, the internal structure of different phrase types such as the NP, the VP, the PP and so on, the constituent structure of the clause and the structure of complex clauses. The descriptive task of a structural grammar is to describe the internal structure and the distribution of these syntactic categories and constructions. For instance, in order to describe the NP as a syntactic category one has to find out the kinds of elements that may be combined in a NP and their possible order(s) within this constituent type. The problem for the corpus linguistic methods is that DOBES corpora do not have a syntactic annotation. Neither parts of speech nor phrases such as NPs etc. are annotated. Therefore, the descriptive linguist is forced to formulate indirect search routines in order to identify the intended phrase type, e.g. a NP. For instance, in Hocąk, most NPs end with a determiner on the right edge. Searching for these determiners (e.g. definite and indefinite articles, demonstrative pronouns) could be a way to find NPs in the text corpus. However, many subordinate clauses have a definite article on the right edge too, so they have to be filtered out by a second procedure. Another problem would arise that there are also NPs that have no determiners in this slot. Another possibility would be to search for nouns assuming that they always occur in NPs. This is not possible, since parts of speech are not annotated. In addition, there are NPs without nouns as heads.

So, it can be concluded that the lack of a syntactic annotation hinders the corpus linguistic treatment of DOBES corpora quite a bit. It would be desirable to have a tool for the

automatic or semi-automatic syntactic annotation of DOBES corpora to make them apt for the searches the descriptive linguist needs to analyze the syntax of the target language. This holds for the phrase level, the clause level and the sentence level of syntagmatic complexity.

Another question are grammatical categories that are expressed analytically. In principle, there is the possibility to search for one element of such a construction and then to compare the hits which contain the second element of such a construction with the ones in which this element does not occur. The other possibility is to look for the whole construction, i.e. a combination of two elements that belong to the construction. In the search string one has to specify the two elements by strings of characters and the number of elements that may interrupt this construction by variables (with certain regular expressions). For instance, in Hocąk, the modal meaning 'must not' is expressed by means of a combination of the future suffix – *kje* and a separate word *heesgé* following the verb. Both elements occur independently with a specific meaning, but in combination they have the meaning 'must not' which cannot composed out of the elements. In the Hocąk corpus, this construction has already been identified and was glossed accordingly, cf. (10):

(10) ref ALV022

tx *Ciirášge* *hižą́ paagáxwigi* *hegų* *wažą́*
mo cii-ra-šge hižą paagax-wi-gi hegų wažą
gl house-DEF-also one write(draw)\1E.A-PL-TOP that.way something

tx *hijąhį́nąhižą́ paagáxwigi* *mąįxeté* *cii*
mo hijąhį-ra hižą paagax-wi-gi mąįxete cii
gl different-DEF one write(draw)\1E.A-PL-TOP white.person house

tx *paagáxikjawi* *heesgera* *hąąké heesge*
mo **paagax-i-kje-wi** **heesge-ra** hąąke heesge
gl **write(draw)\1E.A-0-OBL.IN-PL OBL.FIN-DEF** NEG.IN that's.why

tx *hawinį* *'eegi* *jaagu waací*
mo haa-wi-nį 'eegi jaagu wa-ha-cii
gl make/CAUS\1E.A-PL-NEG.FIN and.then what OBJ.3PL-1E.A-live

tx *hanąkwigi* *heesge* *paagáxwigi*
mo ha-nąk-wi-gi heesge paagax-wi-gi
gl 1E.A-POS.NTL.PL-PL-TOP that's.why write(draw)\1E.A-PL-TOP

tx *woogitékire.*
mo woogitek-ire
gl get.angry/mad-SBJ.3PL

ft When we drew a house, **we were supposed to draw the white man's house**, if we drew what we were living in or something different they would get mad.
dt 23/Jul/2007

However, if this is not the case, one has to formulate a complex search or to formulate subsequent searches in order to identify constructions like these.

5 Functional grammar – the onomasiological approach The goal of the onomasiological approach to grammar is to describe in a systematic way the linguistic means by which in the target language a certain general function can be expressed. This approach to grammar requires searching for semantic functions/ concepts and operations that are considered to be necessary more or less for each language. They are therefore considered universal. It is self-evident that there cannot be a complete list of such functions. Table 4 presents a summary of the most important (probably universal) tasks a language has to be able to fulfill.

Table 4 contains general functions such as reference, possession, and spatial orientation which are fulfilled by various formal means cross-linguistically, but also intra-linguistically. The latter means that even in an individual language there are different means by which these functions are expressed formally. However, these general functions are too abstract to be searchable in the corpus, since these general functions are not or only indirectly annotated in the glossing tier, or are not or only indirectly coded in the translation language English in the translation line. In order to be able to search these general lexical or grammatical meanings/ functions, one has to find lexical items or construction in the translation language – in the Hocąk corpus, it is English - that express the intended meaning/ function or are at least cues for constructions that express the intended function. In the right hand column in Table 4, lexical expressions and grammatical construction in English are enumerated that may serve as search cues for certain semantic concepts and functions. How one can search certain linguistic phenomena that are cues for certain semantic concepts and functions will be illustrated in the subsequent sections Section 5.1 and Section 5.2. The possibility to search for semantic concepts and function utilizing the information in the translation tier is the major advantage a parallel corpus like the ones of the DOBES projects has over traditional monolingual corpora.

5.1 Time in Hocąk In order to find out how tense is expressed in Hocąk, one has different possibilities to search in the English translation language. One may search for tensed verbs in English such as the past tense form of verbs or the future category expressed by a verb-auxiliary construction. In addition, one may search for temporal adverbials that indicate the time relation of the English clause assuming that in the corresponding Hocąk clause, there will be a similar time adverbial.

For instance, if one searches the standard future construction in English, the will plus verb construction it suffices to search the string "will" in the translation tier. One gets 314 hits of "will" in the Hocąk corpus. The corresponding Hocąk clauses can then be looked at to see if there is a corresponding grammatical marker indicating future tense. In almost all cases, one can find one of the above mentioned allomorphs of the future morpheme *–kje*. An additional possibility is to conduct a combined search across tiers like "will" in the ft tier and NOT FUT in the gl tier, in order to find out, if the hits in English correspond always to the future marker (FUT) in Hocąk. Interestingly, there are cases when we find a potential marker *-nąą* in Hocąk corresponding to the *will*-construction in English; cf. (11).

domain	**basic functions**	**representative concepts and operations**	**lexical expressions and grammatical constructions in English as cues for certain semantic concepts**
apprehension & nomination	an entity is grasped by categorizing and individuating it; it is named by a label or a descriptive expression	categorization, types of concepts, empathy	NUM-N N-SG/PL
concept modification	a concept is enriched, or an object is identified	attribution, apposition, relativization	ADJ-N, PTC-N, N-REL constructions, PRO/PROP-appositions
reference	a representation is related to and delimited within the universe of discourse	determination, deixis, reference tracking	DEM-N, DEF-N, INDEF-N, SAP-PRO, Non-SAP 3rd person pronouns
possession	the relation of an entity to another one is established or inheres in one of them	possession in reference, possessive predication, external possessors	genitive attribute (*-s/ of*) verbs of possession (*have, belong*) dative of possession (e.g. *carry sth. for so.*)
spatial orientation	an entity is localized in space statically or dynamically	reference points, local relations, spatial and gestalt properties of objects	spatial adverbs N_1 PREP-N_2 constructions with N_1 as the Figure (object localized) and N_2 as the Ground (region/ frame of reference)
quantification	the extent of the involvement of a set of entities in a predication is delimited	quantification in reference and in predication; counting, ordering	N-SG/PL NUM/QUANT-N numeral adverbials cardinal and ordinal numbers
predication	information is attributed to a referent	existence, situation, characterization	X is Y X is a Y/ Xs are Ys there is a X X is PREP NP X is POSS.PRO Y and many more constructions of location and possession
participation	a situation is articulated into an immaterial center and a set of participants and circumstants related to it and to each other	control & affectedness, central vs. peripheral roles, alignment of fundamental relations	Semantic types of verbs as cues for different event types, verb classes

temporal orientation	a situation is designed with respect to its internal temporal structure and limits and temporally related to another situation	situation types, aspectuality, temporal relations	perfective vs. imperfective aspect (only indirectly in English, but see the progressive aspect) verb classes (stative vs. dynamic; cf. test with progressive) **tense** **(past (V-*ed*),** **present perfect (*have/has* V-*ed*),** **present (∅/ -*s*) ,** **future (*will V*))**, temporal adverbials (*yesterday, tomorrow, last month, next Monday*, etc.)
illocution, modality, evidentiality	a proposition is rendered relative to speaker, hearer and reality	speech acts, obligation, volition, possibility, toning, evidentiality	question words, question marks, verb first position as indicator for imperative clause, exclamation mark modals such as *want, like, must, have to, should*, *may, can*, etc.
contrast	a concept or proposition is assessed qualitatively by comparison with similar ones	negation, comparison, gradation, intensification	referent negation (NEG-N), predicate negation (NEG V) **comparison** **(positive, comparative, superlative of the ADJ)** DIM/AUG
nexion	a situation is expanded into a complex one, or several situations are linked together	speech reproduction, complementation, interpropositional relations	coordinating and subordinating conjunctions (such as *and, but, while, because* etc.) as cues for interpropositional relations, coordinate clauses and subordinate clauses
communicative dynamism	a proposition is articulated in foreground and background	discourse structure, functional sentence perspective (topicalization, focusing, **emph**asis)	there is a X that ... It is X that ...

TABLE 4.: Functional Domains and the formal cues in English (based on Lehmann 2004).

(11) ref WIC008
tx *Taawusiregi* *wiicąt'ɻiranąąną,*
mo taawus-ire-gi wiicąt'ɻ-ire-**nąą**-ną
gl be.dried-SBJ.3PL-TOP be.noticeable-SBJ.3PL-**pot**-DECL
tx *haašak* *hiiranąąną.*
mo haašak hii-ire-**nąą**-ną
gl be.crusty(OBJ.3SG) make/CAUS-SBJ.3PL-**pot**-DECL
ft When they are dry, they **will** become tough, hard like a shell.
dt 07/Jun/2005

The use of the potential marker in Hocąk in this context in (11) makes perfectly sense, since the context is a conditional clause expressing a strong probability in the irrealis and not a future event. The English will construction is obviously not sensitive for this categorial distinction.

Similar search procedures can be performed for the other tense categories. For instance, to search for V-*ed*, one may search for the string `ed\b` in the regular expression mode (in Elan) in the ft tier and get about 3000 hits. Looking through the tx and mo tier of the hits one can see that there is no past tense marker in Hocąk.

5.2 COMPARISON IN HOCĄK Another illustrative example for a fruitful application of the onomasiological search strategy would be comparison. Hocąk has no grammaticalized comparative and superlative. But, how can one find out, how these concepts that are tightly bound to adjectives are expressed in Hocąk. Again, one can look into the ft tier in order to find comparative or superlative forms which can be compared with the corresponding expressions in Hocąk. The cues for comparative to look for in English are the ending *–er* and the marker of the standard of comparison *than*; e.g., *fast-er than his horse.* The *–er* alone is not a good cue for the comparative, because on gets all words that end in *–er* (n=1820 among them *father, after* etc.) and these are mostly not comparatives. Hence, *than* would be the better cue. Not surprisingly, there are only 7 instances in the whole corpus. It seems this is a category that is strongly avoided. The strategies to express comparison in Hocąk are lexical as can be seen for instance in (12).

(12) *tx* *hųųcrá* *šųųkj´ąkra* *hirakísanįk* *hųųcrá* *'ee* *wamąšc´ąąną*
mo hųųc-rá šųųkj´ąk-ra **hirakísanįk** hųųc-rá **'ee** wamąšc´ą-ną
gl bear-DEF wolf-DEF **compared** bear-DEF **he.EMPH** strong-DECL
ft 'The bear is strong**er than** the wolf'(lit. 'The bear **compared with the wolf**, the bear, **HE** is strong.')

In tx hųųcrá šųųkj´ąkra hirakísanįk hųųcrá 'ee wamąšc´ąąną, the asymmetry between the bear and the wolf with regard to the dimension strength is expressed by means of a clause that indicates that there is a comparison and by means of a subsequent clause that focuses the entity that has more of the dimension. This is not a grammaticalized construction, but a possibility speakers invent ad hoc in order to express the concept. There are many other different possibilities to express comparative.

A similar situation can be found in Hocąk with regard to the superlative. One may choose as cue in English the ending *...est/b* for a search in the ft tier. Of course, there are words in English that end in *...est* like *west* or *rest* that are not relevant. The result would be that a) the superlative occurs very rarely, and b) that it is not a grammaticalized construction. One possibility to express a concept like the superlative in Hocąk would be lexically such as in 13.

(13) *tx wąak hakįnųpra waihakra 'ee*
mo wąk ha-kįnųp-ra **wa-∅-hihak-ra** 'ee
gl male **coll**-sibling-DEF **3PL.OBJ-3SG.A-on.top-DEF** he.EMPH
tx hereéną, Adam Little Bear Jr., raašrá 'Aahú Ru'ągá
mo hereé-ną, Adam Little Bear Jr., raaš-rá 'Aahú Ru'ą-gá
gl be-DECL Adam Little Bear Jr., name-DEF Wing Raising-**pn**
tx higaíreeną
mo higa-íree-ną
gl call-they-DECL
ft 'My younger brother, Adam Little Bear Jr., whose name was Raising Wings, is **the youngest** in the family' (lit. translation: 'Of the male siblings, HE (my younger brother) was **on top of them**, Adam Little Bear Jr. he was called Raising Wings.' (cf. White Eagle 1988:v))

The meaning of the superlative is that an entity has - with regard to a certain class of the same or comparable entities - the highest value on a certain dimension. In tx wąak hakįnųpra waihakra 'ee hereéną,, it is expressed that Adam Little Bear is the youngest in the family, i.e. with respect to the dimension youngness, he is the one who has the highest value on this scale. What is astonishing here is that it is the property youngness that is the reference scale. This scale is invoked in the previous context of this text segment, where the speaker speaks of the younger brother using the special term for this in Hocąk.

In the subsequent section, we want to review and evaluate the searching and concordancing functionality of Elan and Poio in order to arrive at list of requirements a software has to offer in order to support semasiological and onomasiological analysis of corpus data.

6 SOFTWARE-BASED SEARCH AND ANALYSIS OF CORPUS DATA In order to be able to evaluate software tools for linguistic analysis we use the same approach taken in Nordhoff (2008) and define a set of values and maxims. Values in this sense define certain criteria to judge the quality of a software from a user's perspective. As Nordhoff states "some of these values can be conflicting", which means that different users prefer different solutions. Still, we consider most of the following values relevant for our purpose of comparing the two packages Elan and Poio (and others not mentioned here, of course) for search and analysis tasks in linguistics. The values are presented as a list of numbered maxims that will later be used to judge whether or not a software tool is better regarding a given value. So the maxims presuppose a certain point of view regarding the values. The reader might not follow all of our assumptions, but all the maxims are derived from the practical application of the ideas to develop a descriptive grammar based on corpus analysis presented in this paper. Our maxims are:

1. Search results should be presented as interlinear text.
2. The user should be able to find the source utterance in its context in the original file from the search result.
3. The user should be able to search on all existing tiers.
4. Relationships among search terms:
   a) It should be possible to define relationships among search terms on one tier.
   b) It should be possible to define relationships among search terms on different tiers.
5. The user should be able to search within search results.
6. Search should be possible in a set of files, not only in one file. The more file formats supported, the better.
7. The user should be able to search for substrings in annotations and use regular expressions.
8. It is better when the user is confronted with fewer dialogs and windows during one search tasks.[2]
9. It should be possible to export searches and search results, in order to save and archive them for later reference.

The following two sections first give an overview of both software packages, specifically of the search and analysis functionality implemented in the tools. Each section will conclude with a summary that contains a rating of the tool according to the maxims we outlined above.

7 Review of Elan search and analysis functionality One of the widespread tools in language documentation nowadays is Elan, a transcription and annotation software developed by the Max-Planck-Institute in Nijmegen, Netherlands.[3] As Elan was developed specifically for transcription and annotation of audio and video files in the beginning, search and analysis functionality was only added later to the software. This led to the current situation, where this functionality is distributed among several menu options within the user interface. Regarding the search types and approaches to corpus linguistic methods for descriptive purposes presented in the first part of this paper, Elan offers the following three features that fulfill some of the requirements the descriptive linguist is striving for:

- Export multiple files as: list of words/annotations
- Search multiple eaf (files)
- Structured search multiple eaf (files)
  - Substring search

[2] This is only an approximation of the quality of the graphical user interface design; a full review of the usability of each tool is left for future research.

[3] http://www.lat-mpi.eu/tools/elan/

Word form	frequency	Word form	frequency
xu̯nu̯	1	xu̯nu̯-i̯g-nąągre	1
xu̯nu̯-i̯g	1	xu̯nu̯-i̯g-ra	1
xu̯nu̯-i̯g-iža̯	1	xu̯nu̯-i̯k	6
xu̯nu̯-i̯g-na̯	1	xu̯nu̯-i̯k-ra	2

TABLE 5.: Extract from the word list of the entire Hocąk corpus

- Single layer search
- Multiple layer search

The "Structured search multiple eaf" feature is by far the most complex and elaborated. It is in itself divided in three dialogs which are listed above. All of the features work on what is called a "domain" in Elan. A domain in this sense is a batch of files. The user can create a domain, give it a name, and then add Elan files to that domain. Later, within each search and analysis feature, users first select a pre-defined domain and then carry out their search and analysis on that domain. The user is able to do several types of analysis through all of the listed features. The following sections will each describe one of the features, and relate their functionality to the search types that were described in Section 3.

7.1 EXPORT MULTIPLE FILES By the "Export multiple files" feature, the user can export all words or annotations of a batch of files to a simple text file. Figure 5 shows the export dialog for word lists. The user selects the tiers from which to export and defines a token delimiter. The default option is to use the pre-defined delimiters, which tokenize by punctuation. Another option is the frequency count ("Count occurrences" option in the dialog), which is added tab-separated to each entry in the exported text file. If the user chooses the frequency count each word in the export file is then accompanied with a number how often this word occurs in all of the domain files.

Figure 5 shows an extract of a sample export file of the Hocąk corpus. This method allows to some degree the identification of allomorphs of the word/lexeme as mentioned in Section 4.1. The extract shows a list of words with a common prefix *xu̯nu̯* 'small, little'. Prefixed forms appear elsewhere in the list and have to be searched separately. Alternate stem vowels (long vs. short) will also lead to a separation of list entries with common lexical roots. The user is not able to trace back the entries to the corpus. Once the export is done, the user cannot simply jump to the position within the files where a list entry occurs. The export of the full interlinear context of words/annotations is not possible with Elan.

7.2 SEARCH MULTIPLE EAF The second feature to be discussed here is the "search multiple eaf" option. This search functionality allows the user to search in the domain's eaf files for search terms. Search terms can be regular expressions or raw strings. The only other option in the search dialog is to switch on or off case sensitivity. Figure 6 shows the search result dialog for the search term *xu̯nu̯* 'small, little'. In this case, the user is able to jump directly to the occurrence of the search term by double-clicking on any entry in the result list. In addition, the user is presented with the annotations before and after the search hit. This

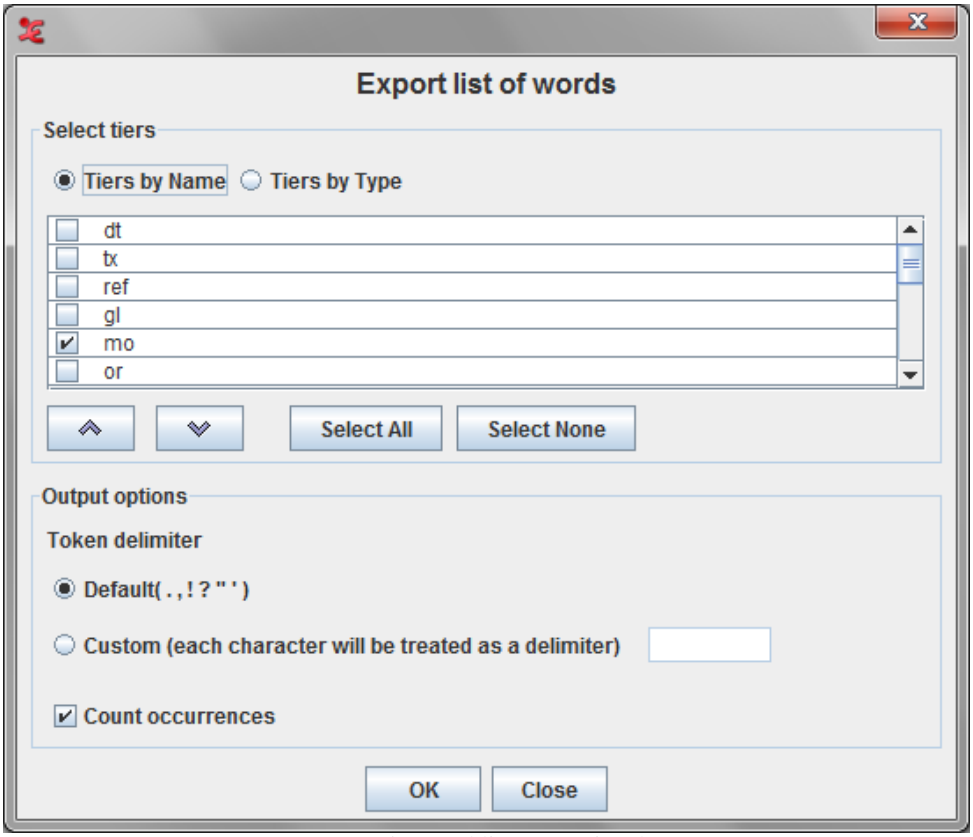
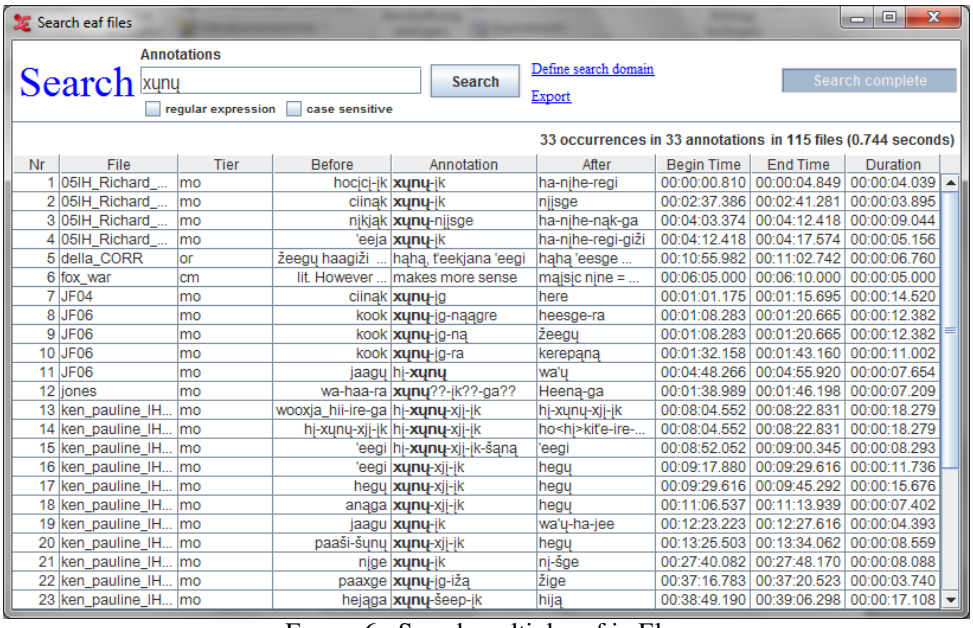


FIGURE 5.: Word list export in Elan



Nr	File	Tier	Before	Annotation	After	Begin Time	End Time	Duration
1	05IH_Richard_...	mo	hocjcj-jk	**xu̧nu̧**-jk	ha-njhe-regi	00:00:00.810	00:00:04.849	00:00:04.039
2	05IH_Richard_...	mo	ciinąk	**xu̧nu̧**-jk	njjsge	00:02:37.386	00:02:41.281	00:00:03.895
3	05IH_Richard_...	mo	njkjąk	**xu̧nu̧**-njjsge	ha-njhe-nąk-ga	00:04:03.374	00:04:12.418	00:00:09.044
4	05IH_Richard_...	mo	'eeja	**xu̧nu̧**-jk	ha-njhe-regi-giži	00:04:12.418	00:04:17.574	00:00:05.156
5	della_CORR	or	žeegų haagiži ...	hąhą, t'eekjana 'eegi	hąhą 'eesge ...	00:10:55.982	00:11:02.742	00:00:06.760
6	fox_war	cm	lit. However ...	makes more sense	mąjsjc njne = ...	00:06:05.000	00:06:10.000	00:00:05.000
7	JF04	mo	ciinąk	**xu̧nu̧**-jg	here	00:01:01.175	00:01:15.695	00:00:14.520
8	JF06	mo	kook	**xu̧nu̧**-jg-nąągre	heesge-ra	00:01:08.283	00:01:20.665	00:00:12.382
9	JF06	mo	kook	**xu̧nu̧**-jg-ną	žeegų	00:01:08.283	00:01:20.665	00:00:12.382
10	JF06	mo	kook	**xu̧nu̧**-jg-ra	kerepąną	00:01:32.158	00:01:43.160	00:00:11.002
11	JF06	mo	jaagų	hį-**xu̧nu̧**	wa'ų	00:04:48.266	00:04:55.920	00:00:07.654
12	jones	mo	wa-haa-ra	**xu̧nu̧**??-jk??-ga??	Heeną-ga	00:01:38.989	00:01:46.198	00:00:07.209
13	ken_pauline_IH...	mo	wooxja_hii-ire-ga	hį-**xu̧nu̧**-xjj-jk	hį-xu̧nu̧-xjj-jk	00:08:04.552	00:08:22.831	00:00:18.279
14	ken_pauline_IH...	mo	hį-xu̧nu̧-xjj-jk	hį-**xu̧nu̧**-xjj-jk	ho<hį>kit'e-ire-...	00:08:04.552	00:08:22.831	00:00:18.279
15	ken_pauline_IH...	mo	'eegi	hį-**xu̧nu̧**-xjj-jk-šąną	'eegi	00:08:52.052	00:09:00.345	00:00:08.293
16	ken_pauline_IH...	mo	'eegi	**xu̧nu̧**-xjj-jk	hegų	00:09:17.880	00:09:29.616	00:00:11.736
17	ken_pauline_IH...	mo	hegų	**xu̧nu̧**-xjj-jk	hegų	00:09:29.616	00:09:45.292	00:00:15.676
18	ken_pauline_IH...	mo	anąga	**xu̧nu̧**-xjj-jk	hegų	00:11:06.537	00:11:13.939	00:00:07.402
19	ken_pauline_IH...	mo	jaagu	**xu̧nu̧**-jk	wa'ų-ha-jee	00:12:23.223	00:12:27.616	00:00:04.393
20	ken_pauline_IH...	mo	paaši-šu̧nu̧	**xu̧nu̧**-xjj-jk	hegų	00:13:25.503	00:13:34.062	00:00:08.559
21	ken_pauline_IH...	mo	njge	**xu̧nu̧**-jk	nj-šge	00:27:40.082	00:27:48.170	00:00:08.088
22	ken_pauline_IH...	mo	paaxge	**xu̧nu̧**-jg-ižą	žige	00:37:16.783	00:37:20.523	00:00:03.740
23	ken_pauline_IH...	mo	hejąga	**xu̧nu̧**-šeep-jk	hiją	00:38:49.190	00:39:06.298	00:00:17.108

FIGURE 6.: Search multiple eaf in Elan

search is applied to all tiers in all files. It is not possible to restrict the tiers to search. The user can export the result list in a tab-separated format.

The search results are not displayed in full interlinear context, only a user-defined context on the same tier before and after the search term is shown.

7.3 STRUCTURED SEARCH MULTIPLE EAF Regarding the search typology presented in Section 3 above, the "structured search" is the most comprehensive facility for search and analysis in Elan. The "structured search" is in itself divided in three dialogs, hence search facilities: a simple substring search over all domain files, the single layer search and the multiple layer search. As only the latter two go beyond the "search multiple eaf" option already presented in the previous section, we will be only concerned with the search in layers here.

Figure 7 shows both search dialogs. The left dialog presents a search for *xu̧nu̧* in all tiers of the type mo. The "multiple layers search" is shown in the right dialog, with sample search for *xu̧nu̧* in all tiers of type mo together with an occurrence of *little* in tiers of type ft. In this example, the constraint between the tiers is set to "No overlap". The green boxes between search term boxes in the dialog allow the user to set different constraints within and between tiers. Constraints between tiers are concerned with different types of overlap, for example "Left overlap" or "Within". Constraints within a tier set the a maximum, minimum or exact distance of two search terms within the given tier, in terms of annotation counts or milliseconds within the media file.

Both dialogs present the results in the lower parts of the dialog as concordances. The user can define the context size of the concordance. An alternative view is given by the

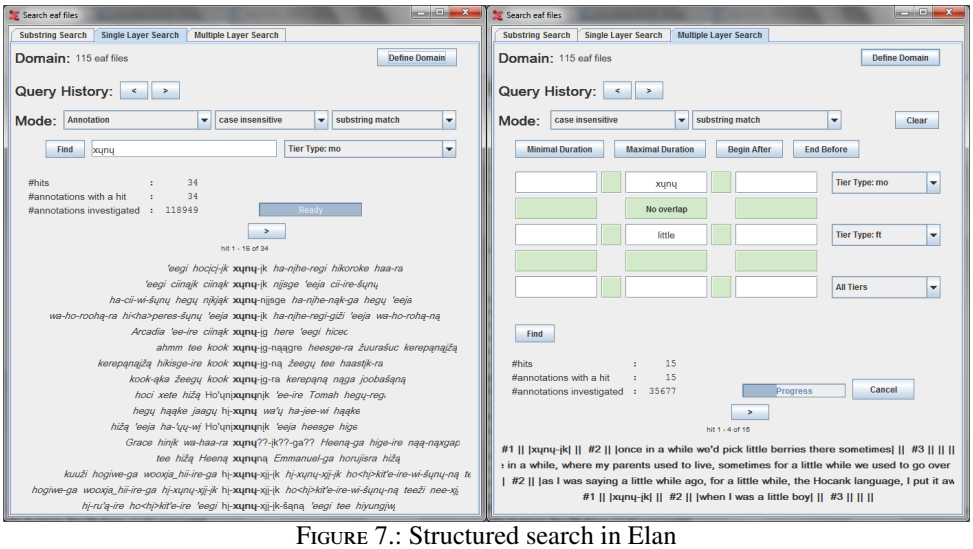


FIGURE 7.: Structured search in Elan

"frequency view", in which all search hits are listed in a table with a count and a percentage. In both views the user can jump directly to the annotation in the eaf file by double-clicking on the element in the list view. The search results may also be exported to a tab-separated file with all timing and context information.

7.4 SUMMARY Regarding the maxims in Section 6, the software Elan is rated as follows:

1. **Search results should be presented as interlinear text:** It is not possible to view search results as interlinear text in Elan. Elan does not even display the annotation for all the tiers at the location where search strings occurs. Only the context within the tiers that was searched in is displayed. Elan does ignore this value completely.
2. **The user should be able to find the source utterance in its context in the original file from the search result.** The user is presented with a configurable context within the list of search results in the simple and complex searches. The user can click on each element in the list and Elan will open another window with the file of the search hit. The user than has to scroll left and right to see the context of the annotation and utterance within the file. We see problems in usability here, but in general Elan implements this feature.
3. **The user should be able to search on all existing tiers:** Elan does allow searches on each tier without restrictions.
4. **Relationships among search terms:**
   a) **It should be possible to define relationships among search terms on one tier;**
   b) **It should be possible to define relationships among search terms on different tiers:**

Elan allows both types of connections between search terms. For some of our users in the project the connection names like "overlap", etc. were not very clear, so we think that usability could be improved. On the other hand the detailed connection types allow every thinkable search combination for the expert user.

5. **The user should be able to search within search results:** Elan does not allow any further searches on the search result.
6. **Search should be possible in a set of files, not only in one file. The more file formats supported, the better.**
   Elan support searches in multiple files through its "domain" concept. But only one file format is supported directly, Elan's EAF format. The user may search in other file types by importing the files first and save them as EAF files.
7. **The user should be able to search for substrings in annotations and use regular expressions.** Elan does fully support regular expressions.
8. **It is better when the user is confronted with fewer dialogs and windows during one search tasks.**[4] Elan's search functionality is scattered among several menu options. So, the user has to open several menus and dialogs to try every possible search type. In the case of the export of word lists the user even has to open another application to apply the search. In our view Elan fails regarding this maxim.
9. **It should be possible to export searches and search results, in order to save and archive them for later reference.** It is possible to export the search results in Elan, but not the searches.

In summary, Elan implements features for 6 of the 9 maxims. Maxims 1, 5 and 8 are violated completely, maxims 4, 6 and 9 only partly or only when we additionally take usability into account (in case of maxim 4). Elan's strength definitely is the structured search that allows advanced search strategies if the user learns about the connection types. Definitely missing is the interlinear view of search results, we also found major restrictions in getting context information from search results. Although the latter is possible, it is quite difficult for the user to get a quick overview of the search result and its context on all tiers at one glance.

8 The Poio Analyzer for descriptive linguists The development of the Poio Analyzer was started because we felt that Elan was not fulfilling all our needs. The software was planned as a tool for descriptive linguists working with data from language documentation projects from the beginning. Once the search typology emerged during the analysis of the Hocąk data, it became clear that Elan is not the right tool for a grammar writer to carry out the analysis. The development of the Poio Analyzer did not start from scratch though, as there was already a library for Toolbox and Elan file access (PyAnnotation[5]) and

[4] This is only an approximation of the quality of the graphical user interface design; a full review is left for future research.

[5] http://www.cidles.eu/ltll/poio-pyannotation

a morpho-syntactic annotation editor (Poio ILE[6]) available. The first provided a common API to the data files with access to the morpho-syntactic annotation, while the latter already contained a view to display utterances in an interlinear style. Both software packages were developed and used within the DOBES project "Minderico –An endangered language in Portugal".[7] All software packages including Poio Analyzer are available for download on the Poio website[8] and are licensed under the GNU General Public License v3.0. Besides the source code there are installation packages for Windows available.

The following section will describe the user interface of Poio Analyzer, with a focus on the requirements that are missing in Elan and that Poio Analyzer implements. We will then give an outlook on future features that are currently work-in-progress before summarizing Poio's features and rating the software.

8.1 The User Interface of Poio Analyzer Figure 8 shows a screenshot of the Poio Analyzer. The main sections of the GUI are marked by numbered boxes. The example data in this screenshot show a search for the regular expression "^ra$" on the morpheme tier, the gloss "DEF" on the gloss tier and the word "\bthe\b" within the translation. The functionality of each part of the GUI surrounded by boxes is as follows:

1. Search tabs allow successive searches. Each "New Search..." tab filters on previous searches. Tabs allow changing intermediate searches by switching between the open tabs. Results are displayed for the current tab.
2. Input fields for search strings to search in each tier. Allows full-flavored regular expression through the updated Python regex module. E.g. character classes like \w or \b fully support Unicode; there is support for Unicode properties, blocks and scripts, etc.
3. Search options:
   a) AND: matches, when all search strings of all tiers match.
   b) OR: matches, when one of the search strings matches.
   c) NOT: inverts the search result.
   d) "contained matches": this value alters the matches in the word, morpheme and gloss tier. If set, the search strings must match within the same word. Otherwise the search strings can match in the whole utterance. For example: if you search for "ra" in the morpheme tier, and for "DEF" in the gloss tier, the normal search will display all matches, where "ra" occurs in a morpheme plus all matches where "DEF" occurs in the gloss tier within one utterance. If "contained matches" is set the result will only contain matches where a word has "ra" in the morpheme tier and "DEF" in the gloss tier.
4. Buttons for searches. Searches may be saved and restored; this will save all the search strings of all tabs.

[6] http://www.cidles.eu/ltll/poio-ile

[7] http://minderico.caorg.pt

[8] http://www.cidles.eu/ltll/poio

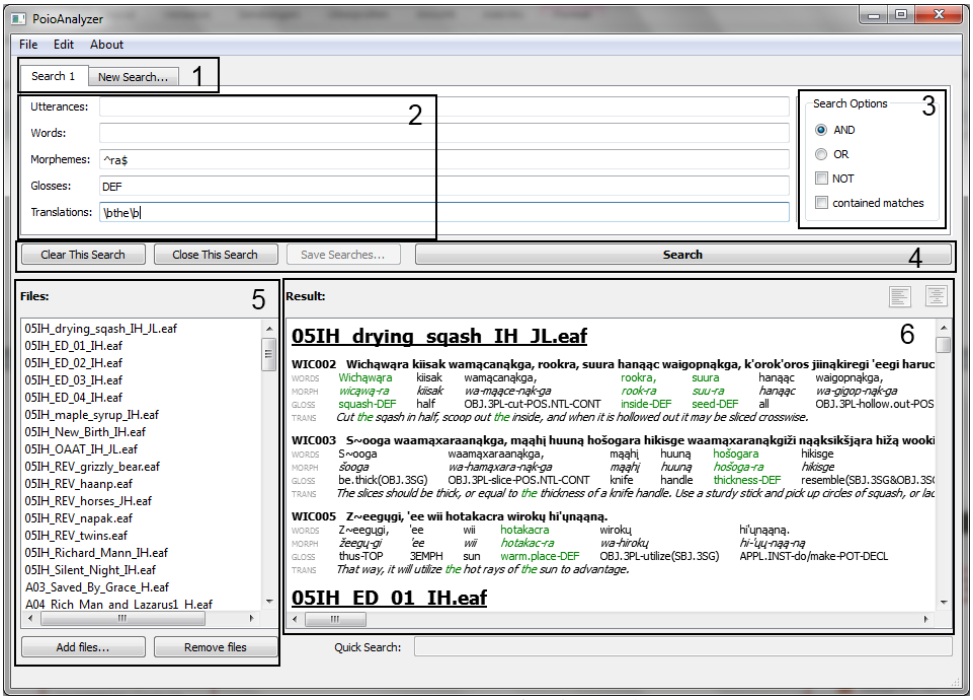


FIGURE 8.: The GUI of Poio Analyzer

5. Here you can add or delete files from the corpus. The result view will be updated whenever the file list is changed.

6. The result view. Matches are displayed in green color within utterances and translations. If there is a match on the word, morpheme or gloss tier the whole word and all its morphemes and glosses will be highlighted in green color. This allows the user to find the matches more easily. All utterances are always displayed with full interlinear annotations.

The screenshot and its description demonstrate two of the most important requirements developed in Section 3: search hits are presented in full interlinear context and the successive search functionality allows the user to conduct searches on previous search result sets. Both features already add value to the search functionality implemented in Elan and provide easier access to search results regarding the search typology developed in this paper. For example, morpho-phonemic processes as mentioned in Section 4.1.2 can be analyzed by searching on the utterance and morpheme tier, with a logical AND operation and "contained matches" enabled. Another example is the search for word internal morphological structure as described in Section 4.3: a search for the gloss "FUT" with results in full interlinear context makes it easier to find out what kind of morphophonemic processes happen between the stems and the grammatical formative or between the combined forms of grammatical

formatives. The biggest advantage of Poio Analyzer here is the view of results as interlinear version.

8.2 Work in progress One of the features that were mentioned in Section 8 was the possibility to archive searches and result sets. This feature is currently not available in Poio Analyzer, but we plan to soon release an update that at least allows saving and restoring searches. Other functionality that we are currently working on is:

1. The possibility to search for set of words, morphemes, glosses, etc. This feature seems critical as it allows for example to search for word classes (e.g. part-of speech) which are not directly derivable from the annotations. In language documentation project there are often preliminary, sorted word lists available, that can be used for this kind of search. In the case of Hocąk a full dictionary is available, which we will use to search for word classes.
2. On top of this we want to make it possible to add part of speech annotation to the data. In the case of Hocąk there is part of speech information available in the dictionary. We are currently investigating the quality of part of speech tagging from this dictionary. Part of speech information would allow search for argument structures as described in Section 4.4.
3. Add statistical evaluation of search result sets. This will be a simple count and percentage value for each tier first. Later, more advanced statistical methods may be added, depending on the needs of the users. The statistical view will also give access to list of words, morphemes and glosses in the result set. Those lists may then be exported and/or used for the "set search" described in 1.

In addition to this we are always collecting ideas for improvement from our users. Depending on the complexity and necessity we will implement anything that seems useful to the descriptive linguist.

8.3 Summary Regarding the maxims in Section 6,the software Poio is rated as follows:

1. **Search results should be presented as interlinear text.**Poio does display all search results as interlinear text.
2. **The user should be able to find the source utterance in its context in the original file from the search result.**Poio does only view the utterance of the search hit. The context of the hit within the utterance is displayed completed, but utterances before and after the search hit are not presented to the user.
3. **The user should be able to search on all existing tiers.**Poio allows searches over all tiers that are relevant for interlinear texts. Additional tiers (that are not part of the hierarchy of a given utterance tier) are not supported yet.
4. **Relationships among search terms:**

   a) **It should be possible to define relationships among search terms on one tier.**

b) **It should be possible to define relationships among search terms on different tiers.** Poio does support both types of relationships, but not as elaborated as in Elan. For example it is not possible to restrict the search on a given tier with information about context size ("[search term 1] with a maximum distance from [search term 2]").

5. **The user should be able to search within search results.**This is fully supported by Poio's successive search functionality.
6. **Search should be possible in a set of files, not only in one file. The more file formats supported, the better.**Poio supports Elan EAF, Toolbox TXT and Kura XML files. Files with different formats may be opened in parallel. The search is carried out over all open files.
7. **The user should be able to search for substrings in annotations and use regular expressions.**Regular expressions are fully supported by Poio.
8. **It is better when the user is confronted with fewer dialogs and windows during one search tasks.**[9]
   Poio follows this maxim, it only consists of one dialog.
9. **It should be possible to export searches and search results, in order to save and archive them for later reference.** Poio does currently not support this feature.

In summary Poio implements features for at least 7 of the 9 maxims. Maxims 2 and 9 are not supported, implementation of features is only planned for future releases. In addition, maxim 3 and 4 are partly violated, as Poio does not support searches on all tiers if they are not part of the interlinear text convention. Combinations of search terms have certain restrictions, especially for searches on a single tier. If we take all the maxims into account Poio supports more of the ideas expressed by the values than Elan. It definitely has an advantage regarding usability, as it was developed as a special purpose tool for search and analysis. Elan, as a general purpose tool, has a lot of other features, like the possible to edit the files during analysis. The possibility to combine search terms in advanced ways is currently a standout feature of Elan.

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[9] This is only an approximation of the quality of the graphical user interface design; a full review is left for future research.

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Digital Grammars: Integrating the Wiki/CMS approach with Language Archiving Technology and TEI

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Although intrinsically closely related to the new field of language documentation, grammaticography is still mostly oriented to the book model, usually falling short of making use of related digital resources and hypertext functionalities. In this contribution, we show and discuss possible or easily achievable advances that can built on top of existing technology such as Language Archiving Technology as developed at The Language Archive at the MPI-PL: Exemplars and examples can be found in multimedia corpora of natural speech events annotated with ELAN and visualized with ANNEX, words and word forms can be linked to lexical entries in LEXUS online-databases, and the precise meaning of theoretical concepts can be given in ISOcat entries or related terminological databases. Independently from LAT, Wiki-technology provides online collaboration and version control and opens even the possibility to address different audiences in related sets of pages, but also poses challenges for the overall didactic structure of a descriptive work. As one of the formats, at least for export and exchange, the XML-based TEI may provide a suitable framework, although many specialized tags would still have to be introduced and formatting and functionalities for these tags still has to be implemented. Generally, synchronization between different versions (e.g., on-line and off-line) poses the most intriguing difficulties, but the advantages (also in terms of Nordhoff's maxims) of hypertext grammars as proposed here are overwhelming.

1 Introduction In recent years, core linguistic disciplines such as language description and linguistic typology have been undergoing major methodological changes due to the rapidly developing digital opportunities and a new interest in the world's linguistic diversity, in particular in endangered languages. The emergence of the new field of language documentation (Himmelmann 1998, Gippert et al. 2006) is both result of and driving force for this development which according to some has the potential for an "empirical turn" or even "revolution" of linguistics and the humanities (Newman 2008, Gippert 2010, Whalen 2004).

Also computational linguistics (natural language processing) has started to work with data from small languages and to make contributions to language documentation (e.g. Bird (2009), Bender & Langendoen (2010)).

While more and more digital empirical data becomes available and used, scholarly work about languages, in particular grammars, is usually still published as paper-oriented texts, mostly as books, book chapters or articles. Connecting scientific texts with their empirical basis and generally with other related resources is still a desideratum; much of the envisaged "virtual research environments" still has to be developed.[1]

The present contribution discusses technology and proposals for an authoring and reading environment for "digital grammars", highlighting the potential role of Language Archiving Technology which does not yet include or develop such an environment.[2] Many of the aspects discussed here exist (or have been proposed) already individually; the goal of this contribution is primarily to provide a survey of the relevant technology, existing or in development, and to propose to combine certain specific aspects and solutions. To the best of my knowledge, several individual features and their combination are proposed here for the first time. The development of a technological solution that includes all of the features suggested here will need at least a medium-sized project with more than one developer and ideally involving several institutions; a project which still needs to find funding. But even at this planning stage the ideas and views put forward in this contribution should serve to stimulate the debate and to gather a group of interested people and institutions.

The focus and general approach of this paper are akin to work by Good, Nordhoff and others.[3] Nordhoff (2008) introduced a number of (possibly conflicting) values that may govern the development of such a system, and for each value one or several "maxims" (roughly, design features) that honour the value. Nordhoff refrains [298] from endorsing any of them, but most are indeed pertinent and should be taken into account in one way or another. Wherever appropriate, I will refer to N's values and maxims, presupposing his discussion.[4]

Slightly differently from Good and Nordhoff, I here use the term "grammar" as representative not only for comprehensive language descriptions but generally for linguistic work based on primary linguistic data (i.e., mostly on recorded speech events as typically obtained in field research), including typological/comparative or more specific descriptive studies. By "digital" I refer not only to the distribution form but imply the broad use of information technology and functionalities such as hypertext links inside and outside the document.

2 Digital (Hypertext) Grammars The possibilities of developing grammars as digital (hypertext) documents has been put forward since the late 1990s (Zaefferer 1998), and recently the topic of general and also of digital "grammaticography" has gained attention (Ameka et al. 2006, Lehmann 2004a,b, Payne & Weber 2007).[5] Nevertheless, there have been only few and partial attempts at developing a digital infrastructure for linguistic research which includes interlinking the linguistic scholarly texts with spoken samples of language use and other resources.

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[1] Thieberger (2006) presented pioneering work akin to DGs as proposed here. See also Thieberger (2009).

[3] See, in particular, Good (2004), Good et al. (2010), Nordhoff (2007a,b,c).

[4] I usually refer just to the maxims by "N[ordhoff]'s maxim #" without citing Nordhoff (2008) in every instance. A list of these maxims is given in the appendix of this volume.

[5] Particularly relevant was the *Conference on Electronic Grammaticography* organized by Nordhoff at the 2nd International Congress on Language Documentation and Conservation in February 2011.

The major special feature of the digital medium is the possibility to *add functionalities* to pages or individual elements of a text. In the case of classical hypertexts, for instance, *links* connect to other parts of the same text or even to other documents, locally or in the World Wide Web. Further functionalities are for instance database queries or playback of multimedia resources. In this way, a text can be embedded into an environment of related external digital resources.

For the purposes of digital grammars as envisaged here, in agreement with Good (2004), I consider the following complementary digital external resources to be most relevant:

1. a language archive with a corpus of annotated recordings of naturalistic and elicited speech events (Good's "texts");
2. a dictionary/lexical database with lexicographic descriptions of individual words and similar units (Good's "lexicon");
3. a resource where the underlying concepts and the meaning of the applied terms are explained and made explicit (Good's "ontologies").

These external resources (which can be respectively abbreviated as "text database", "lexical database" and "terminological database") are discussed in section in more detail.

Based on these, I propose the following features and functionalities as crucial for a digital grammar (DG):

1. The DG is, or can be rendered as, a set of organized and interlinked hypertext pages (see Section 4).
2. Recordings of exemplars (didactic linguistic examples)[6] can be replayed together with their annotation.
3. More relevant examples for specific phenomena can be searched in and retrieved from the text database and/or lexical database.
4. Individual lexical entries for individual words cited in the DG can be looked up in the lexical database.
5. The meaning of technical terms used in the DG can be looked up in the terminological database.

The relations to the three external resources (a), (b), and (c) can be illustrated as in Figure 1. The main relevant functionalities are represented by arrows: (e) green, (g) yellow, and (h) blue.

3 Language Archiving Technology The three external resources proposed to interact with a DG are not new by themselves. In particular, as to the text database, the construction of comprehensive language corpora with annotated recordings of speech events is the very core of language documentation activities as practiced by dozens or even hundreds of projects carried out worldwide in the last 10 years or so.

[6] I follow here the terminology of Good (2004).

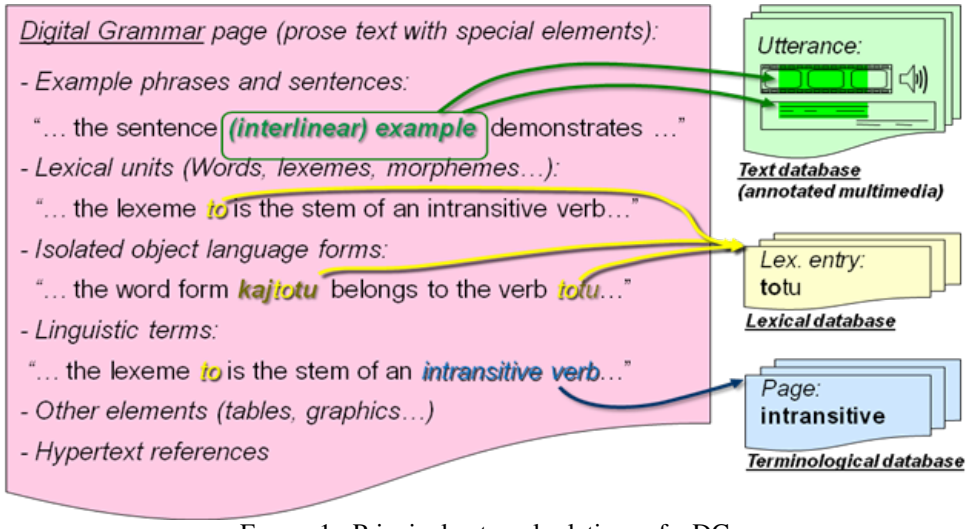

FIGURE 1.: Principal external relations of a DG

Digital lexical databases are probably the earliest language resources created with computers in a field research context. Terminological databases, in turn, are better known in the area of natural language processing, for instance for (automatic or manual) translation. They could add value, however, to grammars, which often have been written on two different levels: in many instances, (1) a specific theoretical conception of a certain domain is explained and the analytical concepts are introduced before [or while] (2) the specific terminology is applied in describing the language (data) at hand.[7] The digital technology allows to keep these two levels apart, so that the DG can focus on the description and analysis, directly employing the terms which are defined and explained in an external terminological database.

One major challenge for all three external resources is: in which form and based on which technology can they be made available for an optimal (in particular, lasting) interaction with the DG? Several solutions may exist for each of them. For instance, there are a few central and several regional language archives, possibly with different standards with respect to file formats and metadata.

Language Archiving Technology (LAT) is a group of interrelated software tools which aims at providing coherent and lasting solutions for the challenges concerning all three external resources identified above. It is developed mainly at the *Max-Planck-Institut für Psycholinguistik* in Nijmegen (MPI-PL) by what is now "The Language Archive". This recently founded unit (earlier the technical group at MPI-PL) is the technological centre

[7] This holds in particular for grammars which are explicitly formulated in a specific theoretical framework. If their terminology is not carefully explained, the grammar runs the risk to be opaque and incomprehensible to anyone not familiar with that particular approach. But also grammars that claim to be "theory neutral", mostly using widely used linguistic terms, need to make the exact meaning of the employed analytical concepts explicit because the "basic" linguistic terms often have varying or vague meanings.

of the program "documenting endangered languages" (DOBES, funded by the Volkswagen foundation), which was one major reason for developing LAT.

The LAT suite is comprised of a well-known tool for annotating audio and video language use data, ELAN (Wittenburg et al. 2006), an online service for creating and accessing lexical resources (cf. LEXUS Ringersma & Kemps-Snijders 2007), and tools for metadata-based access to resources using the IMDI metadata standard (Team 2003).[8] Metadata can be created with a dedicated editor and now with the ARBIL tool (Withers 2009), and the archive can be browsed and accessed with the IMDI-browser. With the LAMUS tool (Broeder 2011), authorized users can upload resources to the archive while consistency checks are performed. User and access administration is done with the AMS tool (II). The resources can be explored online with tools such as ANNEX/TROVA (for multimedia with annotation created with ELAN), LEXUS (for lexical data) and IMEX (for images). Last but not least, the central ISOcat data category registry (Kemps-Snijders et al. 2009) allows defining concepts to which all resources can refer so that different terminologies can be made interoperable.

Most importantly, the language archive has been built with sustainability and long-term-preservation in mind. It is one of the very few archives which have an institutional commitment (for at least 50 years). It uses persistent identifiers (PIDs, cf. CLARIN) to ensure that objects can be cited and recovered even if the infrastructure and location of resources changes (cf. N's maxim 24). Several local and regional archives worldwide are adopting the LAT infrastructure. Even if the technology is bound to change, new technology will be backwards compatible and many other independent developments will at least be interoperable with LAT and its successors.

Crucially, no module for developing grammars (in the broader sense, empirical linguistic work based on speech data) is part of the LAT suite so far, although the basis for building such a platform and integrating it into the existing technology exists. Therefore, LAT is an ideal environment for the development of a digital grammar authoring environment, which is one of the most important points of this contribution. In the next paragraphs, I will discuss the LAT solutions for the three external resources one by one.

The first external resource identified above, the text database for a digital grammar (DG), can be precisely a LAT language archive with IMDI sessions containing ELAN (`.eaf`) files and the multimedia files they annotate (see figures 2 and 3). An archived ELAN file can be referenced to by its PID, and the ANNEX tool can be used to display and play specific parts of a recording, for instance one sentence of a text, together with its annotation. This allows implementing N's (2008) maxims 1 & 2 (regarding accountability): each example/exemplar can be traced back to a real utterance. The context of the examples is also immediately accessible in an ELAN file (N's maxim 4). Using searches (e.g., with the LAT online tool TROVA), more examples can be found in the corpus (the text database) and also be displayed in ANNEX (N's maxim 3).

Creating and exploring lexical databases (LDs, the second external resource of DGs) is the very purpose of the LEXUS tool. Currently many LDs in LEXUS have been imported from other tools such as toolbox (formerly shoebox), and interchange with other lexical

[8] The IMDI-standard is now being superseded by a new CMDI standard developed in CLARIN, the current pan-European initiative to create, coordinate and make language resources and technology widely available and readily useable, one of the core pillars of developing the "Digital Humanities" Schreibman et al. (2008).

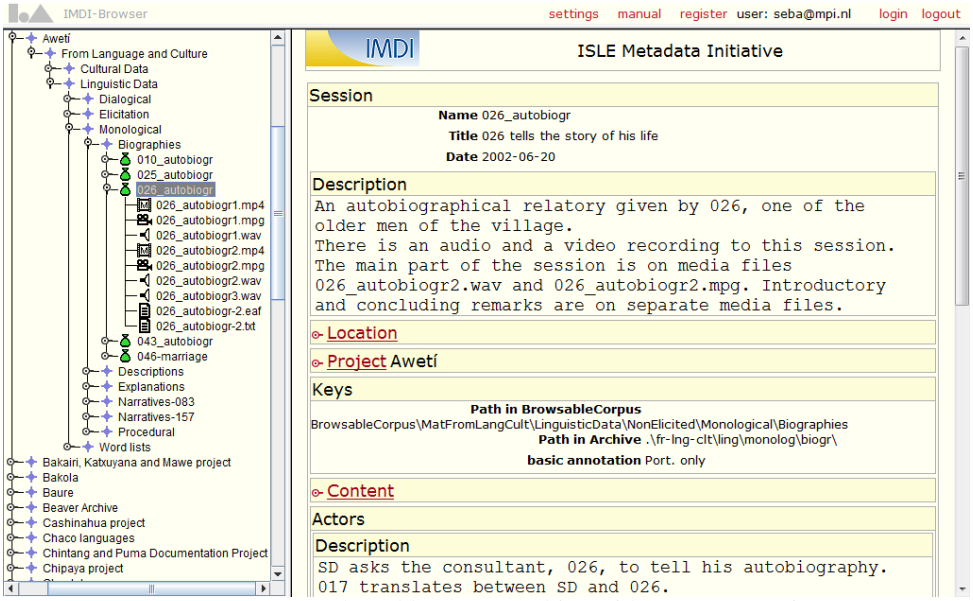

FIGURE 2.: A LAT based language archive with an IMDI session

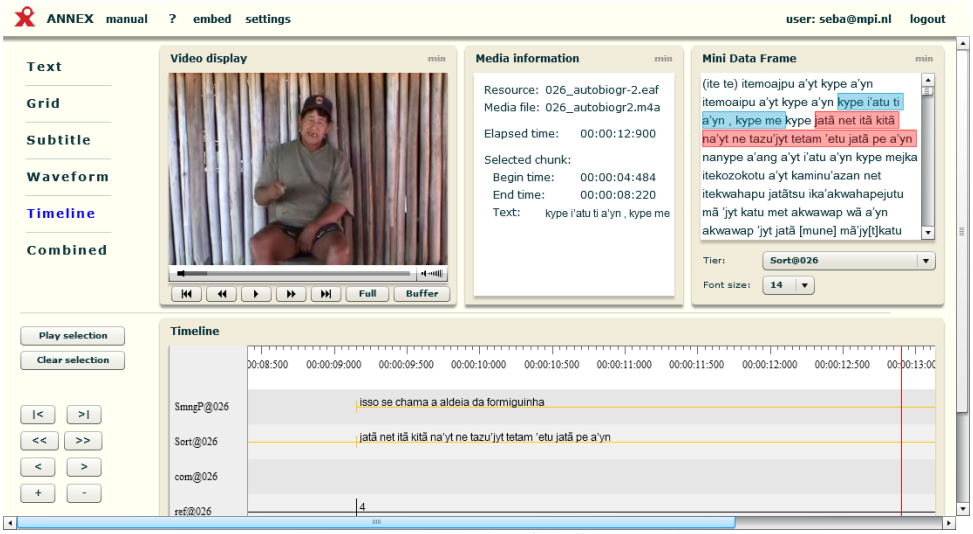

FIGURE 3.: An ELAN annotation file displayed in ANNEX

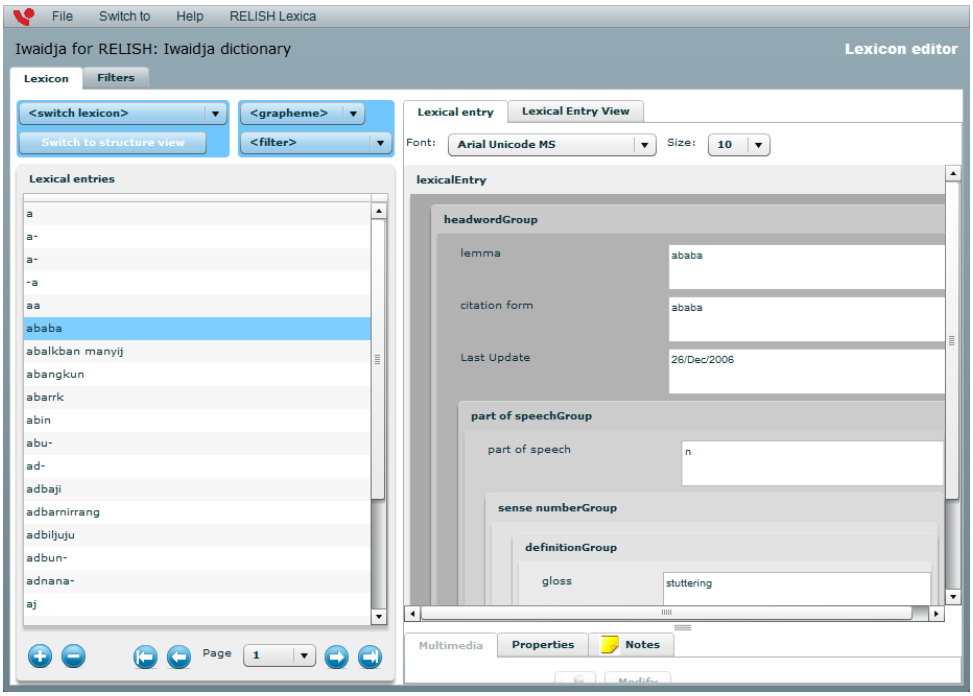

FIGURE 4.: A LEXUS lexicon

database tools will continue to play an important role.[9] Still, differently from Toolbox, LexiquePro, FLEX and other lexical tools, LEXUS relies on the ISO standard LMF (Francopoulo et al. 2007); see also Ringersma et al. (2010) for LDs and is designed to provide full multimedia support.[10] Although work on a stand-alone version is making progress, LEXUS is fundamentally web-based, and uses also PIDs so that integration with other tools is straightforward.

Finally, the purpose of the more recent ISOcat data category registry is to be a central location where definitions of terms for all areas of linguistics and language technology can be provided so that documents and other resources can refer to them. By defining relations between different entries (the "substantive" in one framework can be very close to equivalent to the "noun" in another framework), language resources are prepared for the semantic web (The World Wide Web Consortium 2011, Good et al. 2010). As such, ISOcat can be a central reference or starting point for the terminological database as proposed here. This holds for Good's 2004 "general", "subcommunity" and "local ontologies" alike, which in ISOcat can

[9] The ongoing RELISH project at the MPI-NL, University Frankfurt and Institute for Language Information and Technology at the East Michigan University aims at making different lexical resources, in particular LEXUS (LMF) databases and LIFT-compatible databases interoperable.

[10] Very recently, the LEXUS tool has undergone a complete re-implementation, and more major improvements regarding user interface and functionalities are foreseen for the next future. For instance, it is planned to integrate LEXUS with ELAN so that semi-automatic glossing of sentences and texts based on lexical data (at least including functionalities known from Toolbox or FLEX) becomes possible.

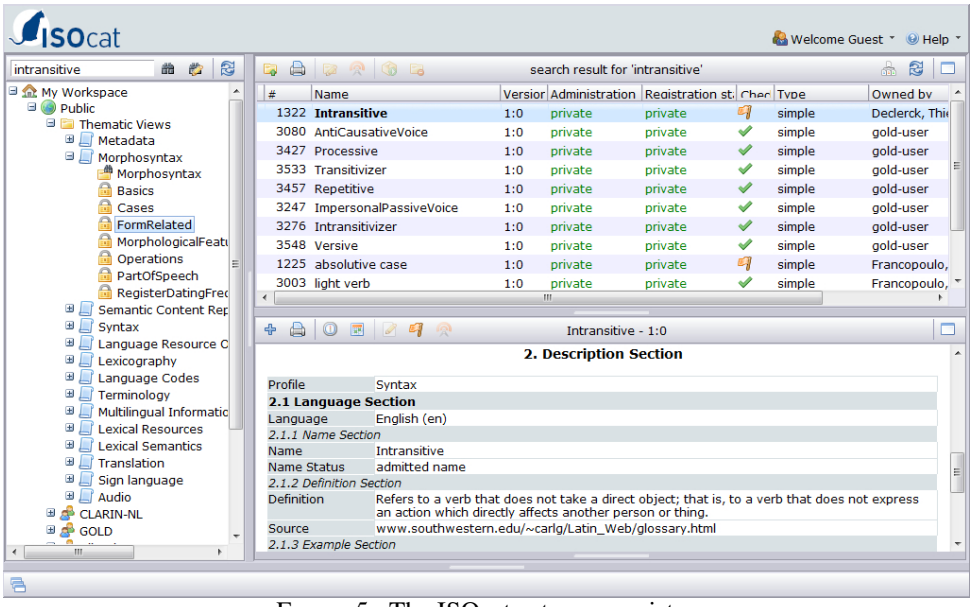

FIGURE 5.: The ISOcat category registry

be distinguished by creating "collections" of terms. The GOLD (Farrar & Langedoen 2003) terms have been included in ISOcat by the RELISH project and are available as one such selection.

Possibly, for the purposes of descriptive linguistics, at least some frameworks will need a more integrated terminological resource with richer explanations than the small text-only technical definitions that are usually given in ISOcat. We propose that such frameworks build their own reference system, for instance in the form of a Wiki, but use ISOcat as a point of reference (where short definitions should be provided). But also less theory-specific descriptions should still link their terms to a corresponding ISOcat entry (which generally will exist, at least for most general terms) in order to guarantee interoperability with other resources. The other LAT tools are all prepared to interoperate with ISOcat, so that this appears to be an ideal starting point for the third external resource, the terminological database (for any kind of online documents involving linguistic terminology).

4 THE WIKI/CONTENT MANAGEMENT SYSTEM APPROACH As stated in (d) above, a DG should be, or should be able to be rendered as, a set of organized and interlinked hypertext pages. Certainly, however, grammarians, descriptive linguists or typologists are rarely prepared and willing to edit hypertext pages by hand;[11] probably only a minority is regularly using semi-logical mark-up like (La)TeX (Knuth 1992).

Nowadays, websites can be created and edited in Content Management Systems (CMSs) where the content can be entered in an environment similar to better known office software. In particular, the more specialized Wiki-technology is now widely known and used

[11] But see the work by Lehmann, presented at the Colloquium on Grammaticography at ICLDC 2.

(in rough technical terms, the functionalities of Wikis are a subset of those of CMSs). Nordhoff (2007a,b,c), elaborating on proposals by Weber (2006), has proposed and developed "Galoes", a Wiki-based online grammar authoring environment.

Indeed, a CMS-based solution has several major advantages, among these:

1. it is independently existing software, so it has not to be developed and maintained or updated by the developers of the DG system;
2. it usually has version control, which allows inspection of the development of the analysis over time, and going back to previous versions (cf. N's maxim 7);
3. it allows collaboration of different users (at different places), and individual contributions are automatically related to their respective authors (N's maxims 11 & 12 on collaboration);
4. user-management (usually included) permits to control rights of editing etc. for different kinds of users;
5. it allows for full-text searches, generating an index or dynamic thematic listings of pages (which can be "tagged" for this purpose), etc. (N's maxim 15).

On the other hand, there are several major challenges for existing CMS or Wiki systems:

1. most additional functionalities identified in section 2 have to be implemented to ensure integration with the external resources and generally with other (e.g., LAT) tools;
2. the Wiki-syntax or display-oriented formatting which usually exists in CMSs is not sufficient for distinguishing the ontological status of the different special linguistic objects;[12]
3. in particular in a Wiki-like environment, the pages are basically unordered, which impedes a didactical linear arrangement in a sequence of chapters, sections and so forth.

In order to allow solutions for first challenge (f), the CMS has to be extensible (preferably open source). It has been discussed in the previous section that the LAT tools (in particular by using PIDs) are prepared for integration and interaction. The second challenge (g) will be discussed in the next section. As to the last point (h) Nordhoff (2008) advocates for non-linear grammatical descriptions, although admitting that this approach creates difficulties for his maxim 20 (on a didactical presentation).[13] I believe this maxim to be important for most scholarly work, even when using digital technology.

Therefore, I propose, at least as an option, a linear organization in units like parts, chapters, sections, etc. where each organizational unit is represented by one hypertext page; units higher in the hierarchy should contain automatically generated listings of links to their respective sub-units (in addition to an optional introduction or overview). Almost every

[12] For instance, marking an object-language entity with the display formatting "italics" does not distinguish between sentences, phrases, isolated word forms, lexemes, syllables etc., each of which may have different associated functionalities. Also, the display formatting may in fact change according to the theoretical framework or the degree of formality/the audience.

[13] The same holds, if less grievously so, for the maxim 21 on the ease of complete reading.

page should have, then, a clearly defined "previous", "next" and "upper" page,[14] although a reader can follow his own path when reading (in) a DG following links to related but distant pages or using tables of contents and indices (N's maxims 17 & 18). Of course, the later introduction of an additional page in the middle of a unit, or the splitting of a page into two (while maintaining their place in the linear sequence of pages), or the rearrangement of the order and groupings of pages, are challenges that need to be solved without imposing the burden of manually updating links or unit numberings on the author.

Nordhoff (2008) proposes to 'tag' the pages according to their place in one or several standardized outline(s) for grammatical descriptions. This can indeed be useful for readers expecting or familiar with a certain structuring (N's maxim 19), but on the other hand, every linguist may have their own approach and every language may require its own best way to describe it (cf. N's maxim 10 on the author's creativity), so some authors may still choose an individual organization of their presentation. This holds much more for typological work or individual papers on specific aspects of a language. Still, 'tagging' pages, e.g. for their relevance and quality (reliability), cf. N's maxims 22 & 23, is an excellent proposal and easily implemented in a CMS-based DG system.

Whether one adopts a (possibly standardized) hierarchical and linear organization or not, individual pages in a CMS allow the author to systematically address different groups of readers separately. This has the potential to overcome a notorious problem of grammars (it may occasionally also concern more specific and smaller linguistic scholarly texts): although the readers may be, for instance, laymen, general linguists (such as typologists), or colleagues that share highly specific theoretical assumptions and background (besides readers who may master different meta-languages, cf. N's maxim 25), there is often only one grammar which either tries to satisfy the different needs in one document (for example by extensive use of footnotes) or else which ignores the needs of one or several groups of potential readers.[15]

A CMS may be set up so that an author can create and manage several individual hypertext pages that all discuss the same topic, albeit for different readers. The organization into different "layers" would be orthogonal to the linear and hierarchical organization, as is shown in Figure 6. In this way, a reader could choose a default layer so that the links usually point to respective pages (if they exist) of that layer. For a given chapter or section the reader still may choose to read another alternative version with, e.g., more or less detail.

It has been suggested by Nordhoff (maxim 9) that templates be provided by the system and applied by the authors of a DG in order to ease the creation of new pages with grammatical information (Black & Black this volume). This might be useful for potentially highly uniform pages, such as pages that describe the form and function of individual morphemes in an agglutinative language (or functional particles in an isolating language), and can be implemented with a CMS or Wiki environment. However, I believe that such a formalized approach would be appropriate for only some parts of a comprehensive language

[14] Such a linear structure also is the easiest solution for the exhaustive perception problem for readers that which to read the complete description (albeit arguably a minority); cf. N's maxim 21.

[15] This problem concerns descriptive grammars and is different from the well-known distinction between descriptive and didactic grammars; the latter are a completely different type of text which usually needs a rather different organization.

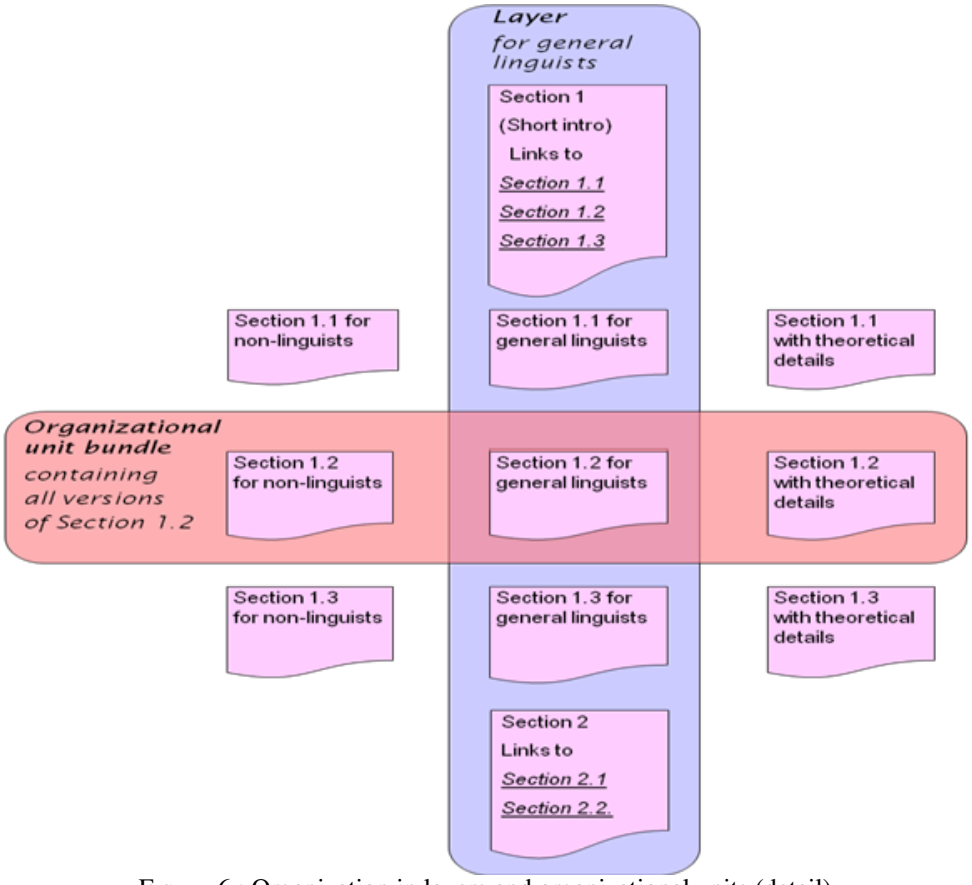

FIGURE 6.: Organization in layers and organizational units (detail)

description, and even less useful for more specific smaller work (see also N's maxim 10 on creativity, conflicting with his maxim 9).

In any case, most CMSs are configurable and flexible enough to allow for the authoring of linguistic scholarly work — given the interconnected questions of the data format(s) and the corresponding suitable editing mechanism are solved.

5 The Text Encoding Initiative There are many different formats of and for digital document, and new formats are developed constantly while others become outdated and, after some years, difficult to access. This holds in particular for proprietary formats such as those generated by commercial office software, which is one major reason why a general authoring environment should rely on open and well documented and widely used formats. Such formats can be developed with XML, the extensible mark-up language, which promises to stay for a long time due to its flexibility to adapt the most different data types, and its wide and growing use. Also, XML has the advantage of being readable both by humans and by machines, which opens possibilities for a later exploitation of DGs by other applications, and their integration into future larger "virtual research environments". This is one of the most promising paths that digital methods currently provide for linguistics (Bender et al. 2010).

We therefore argue that a DG should have XML as one of its central data formats. We say "one of" and not "the", because any online authoring environment will certainly conceptually have to deal with several formats, at least some of which will be technically different one from another. For instance, there will be a format for display (e.g., HTML), a format for representation in the computer memory (the internal working format), a format for saving the work into digital file(s) for backup and/or exchange purposes, one for print-outs (e.g., PDF), perhaps another one for distribution in a stand-alone application, maybe still another one for entering and editing of the content by the user (such as Wiki-markup), and so forth. With XML as one basic format, some formats (such as HTML and PDF, perhaps via TeX) are possibly generated by the CMS without need for any further developments. The better structured the XML format, the more likely it is to take over several of these functions, relieving the burden of developing (often error-prone) routines for converting (parts of) the work from one format into another, some of them bi-directional, which are part of the challenges for the development of such an infrastructure. Also, based on XML, the data and description can later easily be used and manipulated for different purposes (cf also N's maxim 26). There are several CMSs that have an underlying XML format (e.g., Mapix, Baryshnikov, generally, see Content Management Directory).

Even if XML as one central format for the DG is granted, there are an infinite number of possibilities for the concrete elements and their structuring. Again, it is advisable to adhere, as far as possible, to existing standards. It seems to me that the standard being developed by the Text Encoding Initiative (TEI) is the most promising candidate, as it is widely recognized, particularly in the humanities, social sciences and linguistics (being used by almost 150 major and minor projects).[16] There already exist first attempts at integrating TEI-XML in CMSs (Schlitz 2010).

[16] Another candidate is the format used by the XLingPaper project, cf. Black (2009, 2010), Black & Black (this volume), Simons & Black (2009). Compatibility and interoperability will have to be carefully checked.

The TEI guidelines (TEI Consortium 2009) specify encoding methods for machine-readable texts, making concrete proposals for XML elements, attributes and their use and arrangement. XML can be the basic format for several purposes, in particular publishing (Reed & Sewell 2009). There are specific parts of the TEI guidelines that deal with entities relevant for the linguistic analysis.[17] Still, there are potentially many entities which are specific to linguistic descriptions (in particular, interlinear text[18]). It seems advisable to add to the TEI guidelines a chapter or sections with elements for the specific needs for linguistic description, and there is an interest by members of the TEI consortium in adding this (Laurent Romary, p.c.).

On the other hand, the linguistic terminology varies among linguists and frameworks, and at least for certain parts of the terms applied in a language description this may well always be the case,[19] despite the recent attempts at proposing a basic or universal common set (e.g. by GOLD [see references] or Dixon's "basic linguistic theory", cf. Dixon (2010)). Therefore, for each DG the applied elements should be extensible beyond those foreseen by even a dedicated TEI module (cf. N's maxim 10 on creativity). Also, all elements should be configurable with respect to the following properties:

1. display/formatting (font properties, possible ontological distinctions), which may vary for different layers directed to different audiences (cf. N's maxim 8);
2. primary associated functionality (usually accessible by mouse-clicking on the item);
3. possible additional secondary associated functionalities (possibly accessible by a context menu or similar).

For illustration, three types of entities are probably referred to in any grammar, and would represent dedicated XML elements with the properties exemplified in Table 1.[20] Similar units and possibly further associated functionalities are needed for many other entity types on the phonetic, phonological, morphological, syntactic and semantic levels of linguistic description.

These associated properties are part of the DG infrastructure and in principle independent of the TEI recommendation for elements and their attributes (or any other XML serialization), although some aspects of the functionalities may depend on the XML structure (such as the representation of homonym disambiguation by an attribute in the case of lexical words in Table 1).

6 VERSIONING AND PUBLICATION As many major reference works in the digital world, comprehensive language descriptions are not limited to static documents but they should be "liv-

[17] In particular, Section 17.1. "Linguistic Segment Categories", but also parts of chapter 8 "Transcriptions of Speech" and chapter 9 "Dictionaries".

[18] For explorative studies, see Bow et al. (2003b,a), Hughes et al. (2004). Also Palmer & Erk (2007) propose a dedicated XML representation of interlinear text. The DG environment should build on this and similar previous work.

[19] This corresponds to Good's 2004 "subcommunity" and "local ontologies".

[20] Note that the ontological type "syntactic unit" aims at arbitrary (e.g., inline) quotations of object language syntactic units. The "see interlinear glosses" function does not render interlinear text exemplars superfluous; these would continue to be the main type of example which should be displayed as such right away by default.

Linguistic/ ontological Type	Tags and properties	Formatting	Main functionality	Possible secondary functionalities (tooltips and the like)

syntactic unit (sequence of words)	`<dg:Synt.Unit>`
	`he goes`
	`</dg:Synt.Unit>`
		he goes italics, roman	play media file	see interlinear glosses
				see syntactic tree
				jump to lexical entries for individual words

individual word	`<dg:Word>`
	`goes`
	`</dg:Word>`
		goes italics, roman	see interlinear glosses for morphs	jump to corresponding lexical entry (offering choice between homonyms)
				play media file if exists

lexical word	`<dg:Lex.Word homonym.number=1>`
	`go`
	`</dg:Lex.Word>`
		$go_1{}^{W}$ italics, roman, superscript W, subscript 1	jump to lexical entry (taking homonyms into account)	show meaning
				show word class
				show occurrences of forms of the lexical word in texts

technical term	`<dg:term ISOcat="intransitive verb" PID="...">`
	`intransitive`
	`</dg:term>`
		intransitive roman, upright (in formal context maybe sans serif)	show definition from ISOcat (or go to ISOcat entry)	go to explanation in theory-specific Wiki go to page in grammar where this entity is discussed

TABLE 1.: Linguistic entities, their XML representation and associated properties

ing" — often they need to be extended and revised as our knowledge about the language increases (cf. N's maxims 5 & 6). This may hold, albeit in minor extent, also for smaller and more specific digital documents about particular aspects of one language, or for typological work which discusses data from different languages. A CMS solution promises to be an appropriate basis for the implementation of digital grammars as advocated here for the reasons discussed in Section 4 (particularly, version control and management of multiple users). Still, "living documents" in general and digital grammars in particular present a number of challenges:

1. there should be only one central "master" instance of the DG which is maintained up to date;
2. other instances and copies, possibly in other formats (e.g., for distribution), should be derived from that master instance;
3. a certain version of the DG (e.g., a copy derived and distributed at a certain point of time) should be a citable reference (N's maxim 24);
4. the DG ideally should be editable when working with speakers "in the field" (N's maxim 13).

Two main possible derived formats as suggested in (b) are:

1. book or paper versions for reading without digital equipment, e.g. in libraries and in the field (N's maxim 27);
2. stand-alone offline digital versions for distribution and reading on computers or similar devices (N's maxims 13 & 16).

The requirements for these two versions are radically different. The paper version needs a linear order of all pages, good formatting on all levels (individual XML elements, see last section, interlinear texts taken from the annotated corpus, sectioning, cross-references, etc.) and a consistent system of citing elements of the primary data (recordings) and their annotations in an appropriate form. Selected parts of the terminological and lexical databases and of annotated texts (without primary multimedia data) can be included.

In addition, a stand-alone digital version should try to maintain most of the functionalities of the online DG, and therefore include relevant parts of the text database with their primary multimedia data. This not only needs large storage capacities, it also raises possibly complex issues of reorganizing and redirecting the many links so that they point to offline copies of the associated databases. These issues also turn up when it comes to citing specific parts of the DG and/or their associated databases; the specific version should be identified technically so that the relevant state of the work at the respective point of time can be retrieved although by default external links to a DG and its associated databases may prefer to point to always the current version (cf. N's maxim 6 on actuality).

Requirement (a) and generally principles of global availability suggest that the central master instance be online on some central server, as usually is the case of a CMS or Wiki. One master instance on a central server would also allow for automated backups (N's maxim 14 on safety) and (semi-)automatic curation, e.g. transformation to new formats

when current formats become obsolete. Both issues are major challenges for the general goal of data sustainability (cf. Bird & Simons 2003).

However, this requirement conflicts with requirement (d) — on many field sites there is no access to the internet. Allowing for editable offline instances of a DG posits even more complex problems of linking than in the case of offline distributions for exploring and reading. In particular, the need for synchronization of different versions (typically, an offline instance edited in the field with the central online instance) introduces many complex technical issues. Some may be addressable by using an appropriate XML format (see section 5) and established "diff", "patch" and versioning software (such as Apache Subversion or similar revision control systems). Others may require "logging" of changes and their "replay" on the central instance, in particular if changes involve the external databases or major rearrangements of the DG. Although the need for offline editing is obvious for use by field linguists, this feature certainly will take much more time than other aspects of the development of a DG.[21]

7 Conclusion The time seems ripe for the development of a general environment for digital grammars. Much of the necessary technology is available, in particular the technology for the primary external resources connected to a DG: text, lexical and terminological databases. Specifically, I have argued that Language Archiving Technology (LAT) provides solutions for many of the required functionalities. The same holds for the internal system of the central part of a DG itself, which can be implemented as a special adaption of a standard content management system (CMS). However, there are specific needs for implementing the necessary functionalities of a DG, which requires proper technical interconnection of the different resources and therefore a more specific mark-up of the main text and special elements of a DG than most CMS systems provide by themselves. In particular, I have argued that one central format of the body of a DG should be XML, as far as possibly adhering to the recommendations of the Text Encoding Initiative (TEI) and perhaps extending them. Other aspects need to be better defined and discussed, in particular the question of a suitable editor.

It seems obvious that developing and implementing such a DG environment is a project which cannot and should not be undertaken by one person, or even a small circle of people. Technical and linguistic knowledge of different areas is needed, and in order to be of use for a larger community, representatives of that community must be involved in the development. On the other hand, one central place where the development takes place seems necessary, in order to guarantee a coherent and integrated (although extensible) system.

The Language Archive, the home of LAT, is the obvious candidate for leading the development and hosting a DG environment as outlined in this contribution. Interested linguists and technologists are invited to get in contact with the author so that a community that leads and accompanies such a project can be formed.

[21] This can be seen by the development of the lexicon software LEXUS at the MPI/TLA: although a known demand since its beginning, the offline version of LEXUS is still in an experimental stage.

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From Database to Treebank: On Enhancing Hypertext Grammars with Grammar Engineering and Treebank Search

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This paper describes how electronic grammars can be further enhanced by adding *machine-readable grammars* and *treebanks*. We explore the potential benefits of implemented grammars and treebanks for descriptive linguistics, following the discursive methodology of Bird & Simons (2003) and the values and maxims identified by Nordhoff (2008).[1] We describe the resources which we believe make implemented grammars and treebanks feasible additions to electronic descriptive grammars, with a particular focus on the Grammar Matrix grammar customization system (Bender et al. 2010) and the Fangorn treebank search application (Ghodke & Bird 2010). By presenting an example of an implemented grammar based on a descriptive prose grammar, we show one productive method of collaboration between grammar engineer and field linguist, and propose that a tighter integration could be beneficial to both, creating a virtuous cycle that could lead to more effective and informative resources.

1 Introduction This paper describes how electronic grammars can be further enhanced by adding *machine-readable grammars* and *treebanks*, or sets of structured annotations produced by the machine-readable grammars.[2] Following Good (2004), we understand a descriptive grammar to be a set of annotations over texts and lexicon, including both prose descriptions and structured descriptions. In an electronic descriptive grammar, annotations are illustrated with exemplars drawn from the text but are understood to express generalizations over more examples. This is illustrated in Figure 1, from Good 2004. Machine-readable grammars can be understood as another kind of structured description. Because they are interpreted by computers, they are required to achieve a higher level of consistency, with descriptions of various phenomena integrated to form a cohesive whole (Bender

[1] A list of these maxims is given in the appendix of this volume.

[2] We are grateful to the audience at the Conference on Electronic Grammaticography and an anonymous reviewer for helpful discussion. This material is based in part upon work supported by the National Science Foundation under Grants No. 0644097 and No. 0317826, and the Australian Research Council under Grant No. DP0988242. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

2008b). Implemented grammars can automatically produce annotations over individual examples, which can in turn be aggregated and searched (Ghodke & Bird 2010). This vision is illustrated in Figure 2.

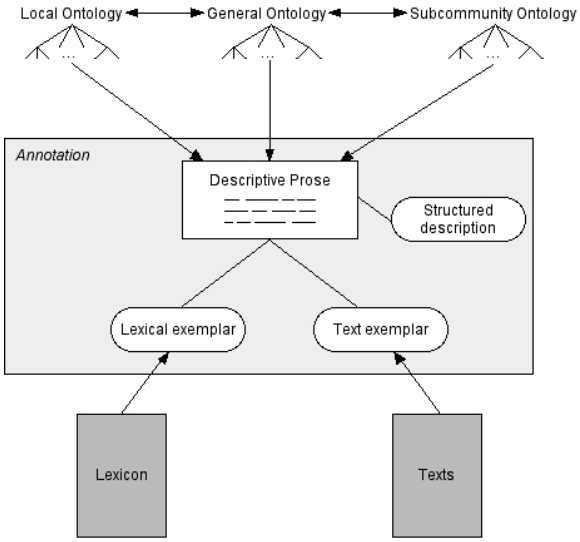

FIGURE 1.: The structure of an annotation (Good 2004)

Our purpose in this paper is to explore the potential benefits of implemented grammars and treebanks for descriptive linguistics and to present to the descriptive linguistic community the currently existing tools which can facilitate their creation. In section 2, we describe implemented grammars and treebanks and give an example of grammar engineering in the context of endangered languages. Section 3 describes treebank search, including use cases relevant to descriptive and documentary linguistics and how it can be integrated into an electronic descriptive grammar. Following the discursive methodology of Bird & Simons (2003) and the values and maxims identified by Nordhoff (2008), in section 4 we explore the impact of augmenting descriptive grammars with treebanks. Finally, in section 5 we explore the resources which we believe make implemented grammars and treebanking feasible additions to electronic descriptive grammars.

2 BACKGROUND

2.1 IMPLEMENTED GRAMMARS Implemented grammars are collections of linguistic rules written in a formalism that can be interpreted by appropriate software in order to apply those rules to linguistic inputs.[3] These inputs can be sentences of the language, in which case the goal is generally to find the syntactic and/or semantic structures assigned to those sentences by the rules (in parsing). If the rules are morphological rules, the inputs are word forms

[3] Implemented grammars of this sort are also descriptive in the sense that they capture linguistic generalizations. For present purposes, we will use the phrase *(electronic) descriptive grammars* to refer to prose statements of linguistic analyses and *implemented grammars* or *machine-readable grammars* to refer to formal sets of rules that can be interpreted by a computer.

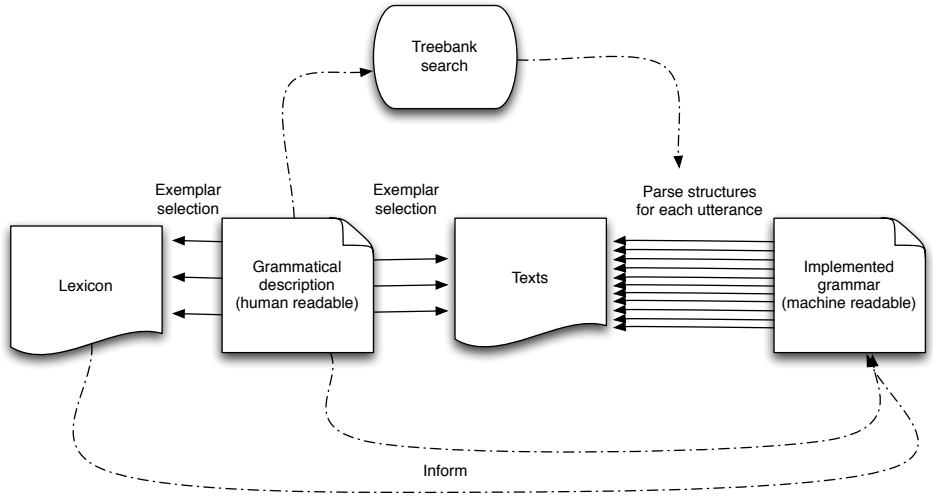

FIGURE 2.: Schematic view of electronic grammars with treebanks

and the outputs morphological analyses of the word forms. Phonological rule sets map surface forms to underlying phoneme or feature sequences. In many cases, implemented grammars are reversible, allowing processing that takes more abstract structures (semantic representations, morphological analyses, underlying phoneme sequences) and produces surface forms. Software for working with such rule sets is most developed for syntax,[4] morphology[5] and phonology,[6] but in the future one can expect other levels of linguistic structure to receive similar treatment. Implemented grammars can be extremely valuable for linguistic hypothesis testing, allowing linguists to check their analyses of different phenomena for consistency (Bierwisch 1963, Müller 1999, Bender 2008b, Bender et al. 2011) and to discover counterexamples to analyses in collected texts (Baldwin et al. 2005).

It is worth noting that while implemented grammars are necessarily *formalized* (i.e., written in some formalism which is precise enough for a machine to handle), they are not typically *formalist*. That is, where a formalist approach to linguistics attributes explanatory power to formal structures and, as a result, typically seeks to state theoretical results in the form of constraints on the allowable formal devices, grammar engineering uses formal structures in order to state analyses and typically favors flexible formalisms which allow for the exploration of multiple analyses (Bender et al. 2011). This practical approach to capturing linguistic generalizations is therefore not at odds with the goals of documentary and descriptive linguistics.

Bender's (2008a, 2010) work on developing an implemented grammar for Wambaya [wmb] on the basis of Nordlinger's (1998) descriptive grammar serves as a proof of concept of the applicability of the computational tools referenced above to endangered languages

[4] e.g., LKB (Copestake 2002), XLE (Crouch et al. 2001), TRALE (Meurers et al. 2002).

[5] e.g. XFST(Beesley & Karttunen 2003) and the morphological engine in SIL's FieldWorks, (Black & Simons 2008).

[6] e.g. XFST

```
wmb-head-2nd-comp-phrase := non-1st-comp-phrase &
  [ SYNSEM.LOCAL.CAT.VAL.COMPS [ FIRST #firstcomp,
                                 REST [ FIRST [ OPT +,
                                                INST +,
                                                LOCAL #local,
                                                NON-LOCAL #non-local ],
           REST #othercomps ]],
    HEAD-DTR.SYNSEM.LOCAL.CAT.VAL.COMPS [ FIRST #firstcomp,
                                          REST [ FIRST #synsem &
                                                       [ INST -,
                                                         LOCAL #local,
                                                         NON-LOCAL #non-local ],
                                                         REST #othercomps ]],
    NON-HEAD-DTR.SYNSEM #synsem ].
head-comp-phrase-2 := wmb-head-2nd-comp-phrase & head-arg-phrase.
comp-head-phrase-2 := wmb-head-2nd-comp-phrase & verbal-head-final-head-nexus.
```

FIGURE 3.: Sample rule types from Wambaya grammar

and language description. Bender (2008a) reports that in 5.5 person-weeks of work, she was able to create an implemented grammar on the basis of Nordlinger's descriptive (prose) grammar that assigned correct analyses to 91% of the exemplar sentences in the grammar and 76% of a held-out test set (one of the transcribed, glossed and translated narratives included in Nordlinger's volume).

Our purpose in citing these numbers here is to show the feasibility of grammar engineering in the context of language documentation and to emphasize its relative inexpensiveness: The grammar engineering effort built on Nordlinger's original fieldwork and analysis, and was minor in comparison, representing about 1/20th of the time. Furthermore, this case study illustrates that grammar engineering for language documentation can be done collaboratively: this methodology does not rely on individuals mastering both the skill sets required for linguistic field work and for grammar engineering, a point we return to in section 5 below.

To make the notion of implemented grammars more concrete, we include a set of sample rule types from the Wambaya grammar in Figure 3. These types are written in TDL (Copestake 2000), the formalism interpreted by the LKB grammar development environment (Copestake 2002), and represent part of an HPSG (Pollard & Sag 1994) analysis. The supertype in this set (`wmb-head-2nd-comp-phrase`) describes all rules that allow a head to combine with its second complement regardless of whether it has already combined with the first (a key piece of the analysis of Wambaya's nearly free word order). The two subtypes integrate the constraints on the supertype with those on other types to define the head-initial and head-final variants of the rule (again related to free word order). The rules combine a head daughter with a non-head daughter, and match the constraints on the non-head daughter with the constraints on the second complement of the head-daughter (through the identity tag `#synsem`). These types inherit from further types which handle aspects of the rules such as semantic compositionality and ensure that the non-head daughter is linked semantically to the appropriate role in the semantics of the head daughter.

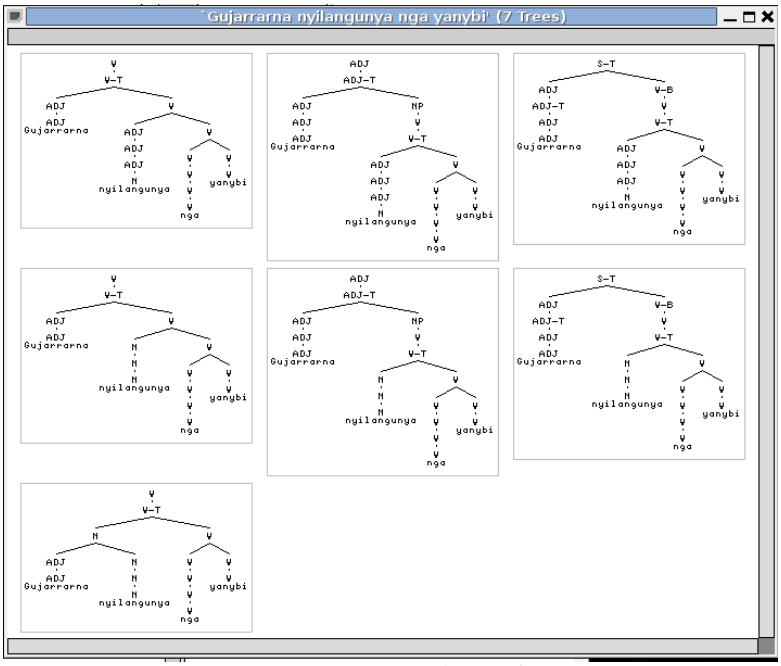

FIGURE 4.: Seven analyses of (1)

Again in the interests of making the notion of implemented grammars concrete to readers who have not worked with them, Figure 4 shows a screen shot of the LKB processing the Wambaya sentence in (1) from Nordlinger (1998:75).

(1) *Gujarrarna nyilangunya nga yanybi.*
two.II(ACC) echidna.II(ACC) 1.SG.A-PST get
'I got two echidnas.' [wmb]

The seven trees shown in the figure represent the seven analyses that the current implemented Wambaya grammar licenses for this sentence. (Note that each analysis is in fact much more detailed; the trees are merely abbreviations of larger syntactico-semantic structures which can be accessed through the software.) Of these seven, the last (bottom left) matches the gloss provided by Nordlinger (shown in (1)). In that analysis, the constituent *Gujarrarna nyilangunya* ('two echidnas') combines with the constituent *nga yanybi* ('AUX get') via the `comp-head-phrase-2` rule.[7]

Returning to the goals of integrating treebanks with electronic descriptive grammars, the examples above highlight two important points about implemented grammars and treebanks: First, annotations derived from implemented grammars make explicit ambiguity in natural language that speakers rarely notice and even linguists often skip over, focusing

[7] This is because the NP 'two echidnas' is the second complement of the auxiliary+verb cluster 'AUX get'. The first complement of the auxiliary is the verb itself.

only on the relevant reading of the examples they are interested in.[8] In most cases, however, only one of the analyses will correspond to a pragmatically plausible reading. Creating a treebank involves selecting that pragmatically plausible analysis, as discussed further in section 2.2 below. Second, implemented grammars and tools like the LKB are not enough to meet the needs of grammar readers looking to use the annotations in order to find relevant examples in a corpus. A separate set of tools is required which can take the output of the implemented grammar and the treebanking process and provide search functionality. Fangorn (Ghodke & Bird 2010) is a treebank search application that fills this need, as discussed further in section 3.

2.2 **Treebanks** A treebank is a collection of natural language utterances annotated with tree structures. Traditionally, treebanks have been created by annotating the tree structures by hand, using a detailed annotation guide. To speed up the process, the text may be first processed with software tools such as a shallow parser or chunker, so that most of the manual annotation consists of correcting and elaborating an initial structure, rather than writing trees "free-hand". The most well-known treebank for English, the Penn Treebank (Marcus et al. 1993), was constructed in just such a fashion. This manual method of creating a treebank has many drawbacks. The most forbidding is the amount of time required, even with the first automatic pass, but there are other problems. Validity of the annotation is one: It is very difficult to maintain consistency when annotating complex structures by hand, particularly when different phenomena can interact in many ways. Another issue is the static nature of these treebanks. Given the amount of time and money needed to create them, once a treebank is annotated, it is rarely updated. This means that out-of-date analyses are kept, even if later investigation suggests a better hypothesis.

Dynamic treebanks, such as the Redwoods treebank (Oepen et al. 2004), are produced by a newer method of treebank construction that uses an automatic parser to process utterances according to an implemented grammar. Manual annotation is still required, but in this case the annotator selects from the possible trees produced by the grammar to nominate the most plausible (with the option of rejecting all trees in case the grammar does not provide a suitable analysis). Since the annotator never edits tree structure manually, all annotations in the final treebank are guaranteed to conform to the implemented grammar. Aside from the benefits of consistency and speed, dynamic treebanks also have the advantage of being easy to update when the grammar changes, as described below.

For this type of treebank, once the text is parsed, the annotator selects the correct tree by making a series of binary decisions based on so-called parse discriminants (Carter 1997). Figure 5 shows the interface of the Redwoods treebanking tool used for this process, with the trees displayed on the left, and the discriminants on the right. Each discriminant represents a single aspect of analysis that occurs in some trees, but not others. These differences could be in the syntactic or in the semantic representation, where a syntactic discriminant consists of a grammar rule and the portion of the sentence it is being applied to, and a

[8] One way that an implemented grammar can be incomplete is by licensing more analyses than are actually warranted for a string. Not all ambiguity, however, is spurious ambiguity (i.e., involving grammatically ill-formed structures). Any grammar with reasonable coverage will necessarily find multiple legitimate analyses of almost any grammatical string it can analyze. One of the lessons of computational linguistics for linguistics is the sheer amount of ambiguity in natural language (Abney 1996).

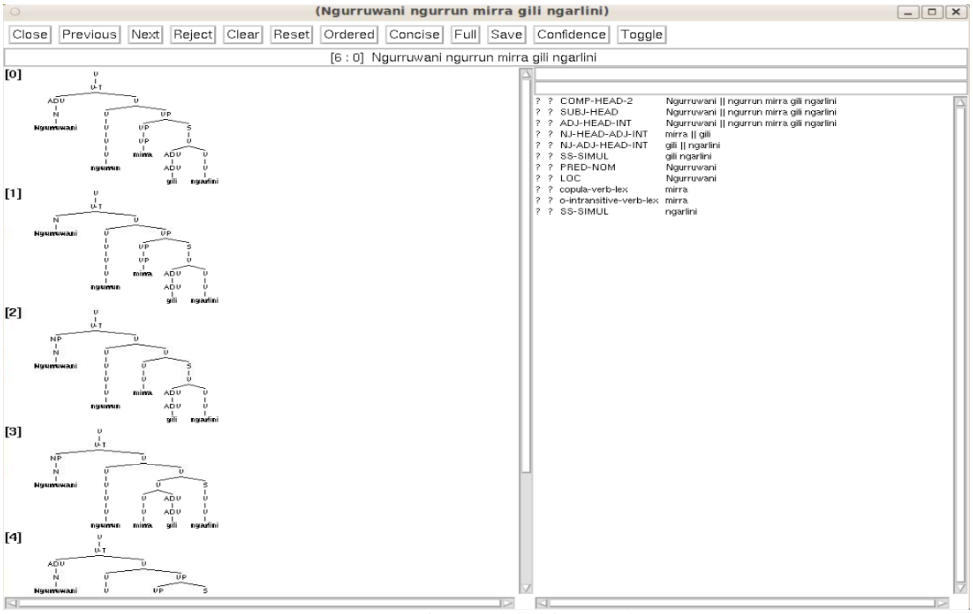

FIGURE 5.: Treebanking tool

semantic discriminant describes a predicate and one of its properties or arguments. An annotator can click on a discriminant and then select *Yes* to indicate that it is correct, or select *No* to exclude any trees that are compatible with this discriminant. Since there are many dependencies between discriminants, selecting one can entail decisions for many others, meaning that finding the correct tree may only require a small number of decisions. These decisions are saved, and can then be used to (semi-)automatically update the treebank after a change has been made to the implemented grammar. When the text is re-parsed with the new version of the grammar, the old decisions can be replayed where applicable, and then the annotator only needs to annotate items that are still ambiguous after the old decisions have been applied. In this way, treebanks can be easily updated to reflect improvements in the grammar without the need for complete (and costly) re-annotation.

In addition to their use in linguistic exploration, these treebanks can also be used to build a statistical *parse selection* model (Johnson et al. 1999, Toutanova et al. 2005), which can be used to rank parser output by probability. While most human-detectable ambiguity requires contextual information to resolve, the large majority of implausible analyses can be ruled out on the basis of sentence-internal patterns. These patterns are probabilistic and very difficult to model with hand-written parse ranking rules, but are well handled by the machine learning (pattern recognition) techniques prevalent in computational linguistics. For present purposes, parse selection is of interest because it makes subsequent treebanking efforts easier. By learning characteristics of the trees selected as correct in a first round of annotation, a parse selection model can be used by the parser to automatically discard the most improbable analyses before the annotator sees them, speeding up the annotation process.

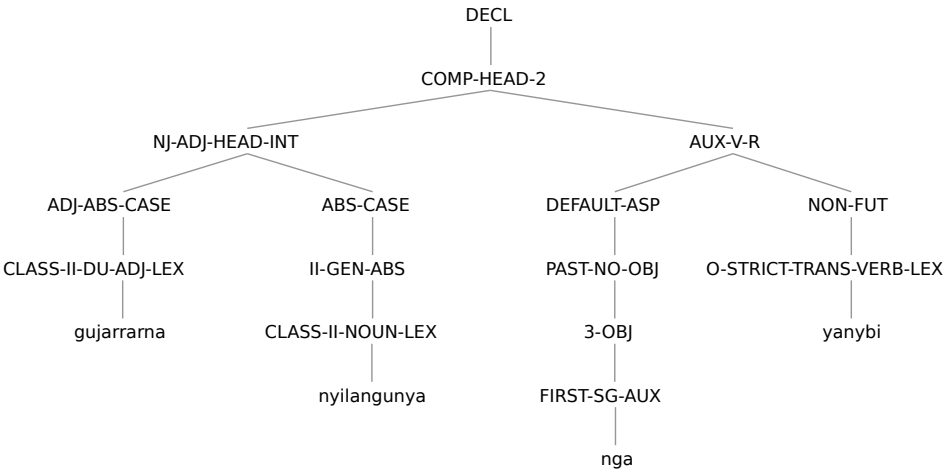

FIGURE 6.: Treebank tree format for (1)

2.3 SUMMARY In this section we have provided background on both implemented grammars and treebanks, with the goal of sketching the technology and methodology available. The following section will build on this to describe how treebanks can be used for linguistic research purposes.

3 USING TREEBANKED DATA Treebank exploration is simplified by the use of specially designed search tools. These tools read in treebanked corpora and on request provide instances of trees, similar to the one shown in Figure 6, that match the sought tree-pattern of linguistic significance from within a corpus. Common features of such tools are: a query language to specify the pattern of interest and a user-interface to view the matching exemplars from the corpora.

Treebank search tools such as TIGERSearch (Lezius & König 2000) and TGrep2 (Rohde 2005) have been available for about a decade now. Only recently, however, with the development of Fangorn (Ghodke & Bird 2010) has a solution become available which allows for efficient search over large-scale treebanks.

3.1 FANGORN Fangorn uses a path-based query language that is a subset of the LPath query language (Bird et al. 2006). For a detailed comparison of different treebank query languages see Lai & Bird (2004).

Path query languages are used to specify tree nodes of relevance. A path is a sequence of required node labels together with operators that state the relationship between consecutive labels. In other words, the path functions as a linear specification of nodes in trees of interest. For example, one interesting property of Wambaya is that modifiers can generally stand alone in argument positions (Nordlinger 1998). A linguist interested in sentences with this property might begin with a query like (2), which finds all parses where a declarative

Vertical navigation		**Horizontal navigation**	
descendant	//	following	-->
ancestor	\\	preceding	<--
child	/	immediately following	->
parent	\	immediately preceding	<-
		following sibling	==>
		preceding sibling	<==
		immediately following sibling	=>
		immediately preceding sibling	<=

TABLE 1.: Query operators and their symbols

clause (label: DECL) has a complement of a verb realized by a modifier (label: HEAD-COMP-MOD-2) below it.

(2) //DECL//HEAD-COMP-MOD-2

The operator // in (2) is a *descendant* operator. Table 1 lists the different query operators in the Fangorn query language. The operators have been categorized into two types: horizontal and vertical, depending on whether they specify dominance or sequential positional constraints. The semantics of the vertical navigation operators are the same as their definition in the context of a tree. Similarly, the names for the sibling operators are mnemonic for their functions. The *following* operator specifies that the node to the right of the operator is temporally after the node to the left of the operator. The *immediately following* operator specifies that the leftmost descendant of the node to the right is temporally immediately after the rightmost descendant of the node to the left of the operator. The *preceding* and *immediately preceding* operators are the inverse of *following* and *immediately following*, respectively.

The first operator in the query specifies whether the query pattern should appear at the root of the tree or anywhere in the tree. For example, if query (2) started with a *child* operator (/) rather than a *descendant* operator (//), then it would match only trees in which the topmost node is a declarative clause with a HEAD-COMP-MOD-2 somewhere inside it.

Query (2) specifies a path consisting of two nodes, however, paths could contain any number of operator-node pairs. Both vertical and horizontal navigation operators can appear at any position in the path. The only restriction is on the first operator in the main path in the query. It has to be either a *child* or a *descendant* operator.

An operator in a path specifies the relationship between the node preceding and following it. In some cases, however, we would want to specify more than one relationship at a single node. For example, we may want to modify query (2) so that the head and complement positions are irrelevant, which means the node under the declarative clause could be either HEAD-COMP-MOD-2 or COMP-HEAD-MOD-2. Each of the two labels has a *descendant* relationship with the declarative clause DECL. Example (3) describes such a query.

(3) //DECL[//HEAD-COMP-MOD-2 OR //COMP-HEAD-MOD-2]

Square brackets after any node in a path are called *filter expressions*, and can be used to indicate alternatives (a split into two or more possible paths) or conjoined constraints on a

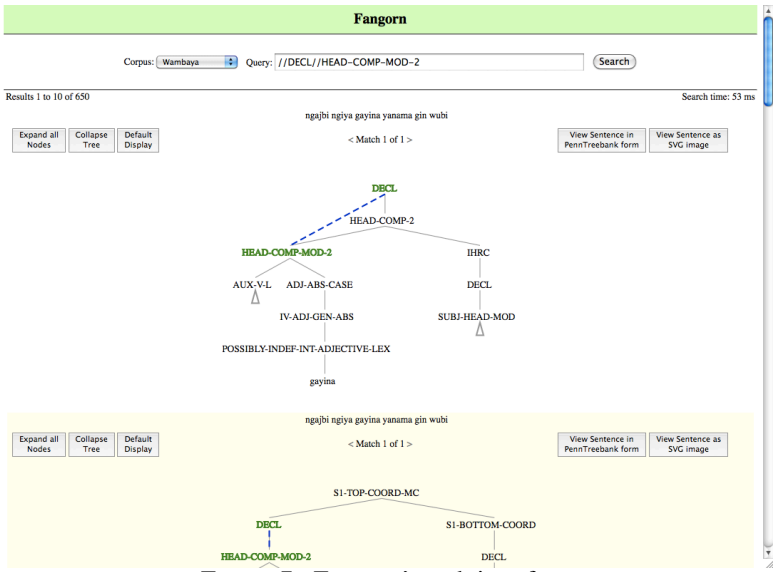

FIGURE 7.: Fangorn's web interface

node as shown in (3). The paths within a filter expression are connected using logical operators AND, OR and NOT to add flexibility to the constraints. Further, since the paths within filter expressions are themselves paths again, queries can have nested filter expressions.

Fangorn uses a web-based user interface, where the page contains a search box and a result display area to show the matching trees. A screen shot of the user interface for query (2) is shown in Figure 7. The left-hand top corner of the display area shows the total number of trees that match the query pattern in the corpus. The first page, showing 10 trees, is displayed by default. The user can choose to navigate to other pages. Each tree may match the query pattern more than once. Hence, the total number of matches within the tree and the match currently being displayed is shown at the top of each tree. Other matches within the same tree can be viewed using the '<' and '>' buttons at the top of each tree. The trees are minimally expanded to show the results in a concise manner, but additional nodes can be expanded or collapsed in the display. The nodes that match the query are highlighted and joined by lines that denote the operators between the nodes. Each matching tree can be exported in either a bracketed format or as an SVG image identical to how the tree is displayed on screen.

Fangorn can be used in a number of modalities, including linguistic exploration, grammar engineering, and cross-linguistic comparison.

Linguistic exploration can be viewed as a kind of "exploratory data analysis" (Tukey 1977), whereby users query for particular lexico-syntactic patterns in a given language, and, e.g., explore the productivity of a construction, investigate the interactions between different constructions, investigate the distribution/behavior of a given construction across different domains (as instantiated in different treebanks), or simply observe the distribution of given lexical items in different syntactic contexts. Resnik et al. (2005) is a good example

of this sort of exploration using linguistic structure, although that work was not tied to a descriptive grammar.

Grammar engineers can use Fangorn to validate a new analysis, by analyzing all instances of the given lexical rule or construction in trees licensed by a grammar. Traditionally, Fangorn has been applied to "gold standard" disambiguated trees. In indexing a larger set of analyses licensed by the grammar (e.g., the top-500 analyses, as selected by a parse selection model), however, it is possible to retrieve all analyses in which a given pattern occurs, allowing the grammar engineer to gauge whether an analysis is adding spurious ambiguity. Fangorn can also aid in the education of grammar engineers, in exploring how the analysis of a given construction is manifested in syntactic trees, and comparing this back to the "source code" for the analysis in the grammar files.

Finally, assuming a comparable label set between grammars of different languages, it is possible to perform cross-linguistic queries to compare, e.g., differences in right-node raising between English and German in a data-driven manner. We come back to this briefly in Section 5.3.

3.2 Incorporating Treebank Search in Descriptive Grammars Good (2004) presents a vision of electronic descriptive grammars as linked to searchable corpora, where exemplars chosen by the author to illustrate particular phenomena can be linked back to their original context, and additional examples can be retrieved from the database. We see the main benefit of treebanks to descriptive grammars as enriching the range of ways in which examples can be retrieved.

Treebank search can be incorporated into a descriptive grammar in two different (and complementary) ways: (i) The author of the grammar can include specific "canned" queries at various points in order to allow the reader to retrieve examples with properties relevant to the discussion (this would of course be in addition to providing exemplars, as is usual practice); (ii) The treebank search interface can be made available to the reader to input arbitrary queries matching their own interests. At present, Fangorn allows searching over tree structures with the nodes labeled by the rule (phrasal or lexical) or lexical type which licensed them, as well as over the words at the leaves of the tree. For the purposes of inclusion in descriptive grammars, it would be useful to extend that search capability to include the other annotations over the data (i.e., glosses and translations). Longer term, it would also be interesting to include searches over the feature structures abbreviated by the tree structures, including especially the embedded semantic representations.

The addition of "canned" queries will be relatively straightforward (once the implemented grammar and treebank are built), and will most likely be done in collaboration between the field linguist writing the descriptive grammar and the grammar engineer developing the treebank (cf. section 5). The exact mechanism for making the canned queries and associated results accessible to users of the grammars is open to debate, but can potentially build off the work of Hashimoto et al. (2007) on lexical type documentation via illustrative positive and negative examples.

Making the search interface itself useful to readers will require documentation. General documentation about the query language will be applicable to all such treebank-enhanced grammars, but information about the implemented grammar licensing each treebank will also be required. The "canned" queries themselves will provide a useful part of this doc-

umentation, serving as models for other similar queries. In addition, the documentation should include a glossary of all of the labels in the treebanks (e.g., names of phrase structure rules, names of lexical rules, names of lexical types, as well as category labels used). Ideally, this glossary would include links to the relevant sections of the descriptive grammar and thus be accessible from those sections as well (following the links in the opposite direction).

3.3 **Summary** In this section, we have given a brief overview of Fangorn, how it can be used to formulate queries, and how those queries could be used to assist readers of electronic descriptive grammars in getting information from an associated treebank. In the following section we reflect further on how implemented grammars and treebanks can help fulfill the goals of descriptive and documentary linguistics.

4 **Values and Maxims** Bird & Simons (2003) structure a discussion of best practices for creating portable (and thus useful and enduring) language documentation around a series of value statements and maxims that follow from those values. Nordhoff (2008) picks up that discussion with a particular focus on how values identified by Bird & Simons influence the form of electronic descriptive grammars and inform the design of software supporting the development of such resources. Nordhoff is focusing in particular on those values that are relevant to electronic grammars with non-linear (i.e., graph-like) structure.

In this section, we explore how the addition of treebanks to electronic descriptive grammars can respond to some of those values, with a particular focus on those that treebanks speak to, either because they can enhance the ability of an electronic grammar to fulfill a maxim or because they would in fact be problematic in some way. Following Nordhoff, we structure the discussion according to the general areas of data quality, grammar creation (by authors), and grammar exploration (by readers). All of the maxims are given in the consequent of a conditional with the associated value in the antecedent, as in Bagish (1983), the inspiration for Bird & Simons's (2003) approach to discussing these issues.[9] This discussion includes both near-term goals using existing technology as well as longer-term possibilities.

4.1 Data quality

(4) Accountability: If we value the application of the scientific method, more sources for a phenomenon are better than fewer sources (Rice 2006:395, Noonan 2006:355).

This maxim is the most obvious win for treebank and treebank search enhanced electronic grammars: If an electronic grammar is paired with a database of interlinear glossed text (IGT), it is already possible to search for some phenomena in that database. The trees in a treebank make much more of the structure of the sentences explicit than even the most meticulous IGT, and thus treebanks make it possible to more easily find examples of a broader range of phenomena (cf. section 3).

[9] Except where noted, the antecedents and consequents are direct quotes from Nordhoff (2008:308–318). Additional citations are provided when Nordhoff indicated other sources for the maxims. Where there are multiple maxims for the same value statement, we have kept them as separate statements or merged them into one according to the most convenient structure for the present discussion. In Nordhoff's terminology, 'GD' stands for 'grammatical description', i.e., what we are referring to here as an electronic descriptive grammar.

(5) ACCOUNTABILITY: If we value the application of the scientific method, every step of the linguistic analysis should be traceable to a preceding step, until the original utterance of the speaker is reached.

As noted above, an implemented grammar requires that the various analyses it implements be integrated into a cohesive whole. The flip side of this is that every tree in a treebank represents several levels of linguistic structure. In grammars such as the Wambaya grammar discussed in section 2.1, these include semantic, syntactic and morphological analyses. Thus, to the extent that the reader is supported in exploring the trees, the trees themselves will help ground semantic and syntactic analyses in previous steps. The connection between the morphological string and the original utterance will have to be handled outside of the treebank, however.

(6) ACCOUNTABILITY: If we value the application of the scientific method, the context of the utterance should be retrievable (Weber 2006:450).

Nordhoff discusses this one in terms of the communicative context (who's speaking, to whom, with what goals, etc). We assume that if this information is documented in the database underlying the treebank, then it should be accessible from the treebank as well. However, another issue relating to context arises for treebanks, namely the importance of preserving the linguistic context. All implemented grammars are in fact grammar fragments, and thus will not necessarily have complete coverage over arbitrary samples of naturally occurring text. With reasonably mature grammars there are robustness strategies (Kiefer et al. 1999, Riezler et al. 2002) that potentially allow for partial analyses in a treebank, but these are unlikely to be applicable or desirable in this application. Thus, a treebank associated with an electronic descriptive grammar will necessarily have gaps, i.e., sentences which are not assigned any trees. In order to preserve the linguistic context of the examples which are assigned trees, and which thus can be retrieved with Fangorn, it will be important to maintain links between the treebank and the underlying dataset.

(7) ACTUALITY: If we value scientific progress, a GD should incorporate provisions to incorporate scientific progress.

Nordhoff notes descriptive grammars are never finished. In the same way, implemented grammars also always have room to grow. It is a major benefit of the Redwoods approach to treebank construction (Oepen et al. 2004) that treebanks can be cheaply and rapidly updated when the grammar that produced them has been changed. Thus modern treebanking methodology makes it possible for electronic grammars with treebanks to rise to this maxim.

(8) HISTORY: If we value the recognition of the historic evolution of ideas, the GD should present both historical and contemporary analyses (Noonan 2006:360).

The same software that supports the creation of treebanks ([incr tsdb()], Oepen & Flickinger 1998) allows for detailed comparisons between treebanks based on different grammar versions. The primary purpose of these comparisons has been to allow grammar engineers to explore the impacts of various changes they have made to the grammar, in terms of which items (sentences) are assigned different (or more or fewer) analyses by one

version of a grammar than another. It is possible that this same software could be adapted to facilitate the exploration of the evolution of analyses either of particular examples in an implemented grammar, or of classes of examples. Doing so in a way that would make it informative for linguists who are not grammar engineers would, however, require significant additional user interface effort.

4.2 Grammar creation The particular maxims that Nordhoff proposes under this heading are specific to the design of a grammar-authoring platform that supports the creation of electronic descriptive grammars, and therefore don't speak to the creation of implemented grammars. Accordingly, instead of reviewing Nordhoff's maxims, we have proposed some of our own that concern the creation of implemented grammars (and thus treebanks), but relate to the same set of values.

(9) Assistance: If we value speed of creation and comparability (across grammars), we should seek to provide means to assist linguists in rapidly creating comparable implemented grammars.

This is in fact the goal of the Grammar Matrix project (Bender et al. 2002, 2010). The Grammar Matrix provides a common core grammar, which defines things such as the format of semantic representations (using Minimal Recursion Semantics (Copestake et al. 2005)), an implementation of semantic compositionality, and general types of rules and lexical entries. In addition, the Grammar Matrix provides a set of libraries of analyses of cross-linguistically variable phenomena. These libraries are developed on the basis of a review of the typological literature, though of course are not assumed to be comprehensive: the project always anticipates the addition of new options within a library, as well as changes to the core grammar. The Grammar Matrix is described further in section 5 below.

(10) Creativity: If we value the individual mind's expressive abilities, support for creating implemented grammars should not preclude the linguist exploring alternative analyses in the implemented grammar.

The Grammar Matrix is in a sense analogous to the prose templates that Nordhoff proposes as part of a grammar authoring platform. Both make it easier to create a linguistic resource (descriptive grammar or implemented grammar), in terms of coverage of phenomena and in terms of compatibility with the relevant set of tools. At the same time, these aids can also have the adverse effect of limiting creativity or biasing analyses towards those anticipated by the creator of templates/libraries of analyses. Compared to prose templates, Grammar Matrix libraries are more difficult to create (represent a larger investment of time and effort) and are likely also more limiting. Both of these effects follow from the fact that implemented grammars require all of their component analyses to interact. On the one hand, the grammar engineers constructing the libraries must design them carefully to be interoperable with all of the options of all of the other libraries (Drellishak 2009:Ch. 2). On the other hand, a linguist attempting to develop an alternative analysis for one phenomenon will find herself hemmed in to a certain extent by the decisions made in the analyses of other phenomena.

Nonetheless, we believe that grammar engineering provides a net benefit for analysis exploration because computers can be harnessed to test the analyses against large data sets

(Bender 2008b, Bender et al. 2011). Thus even though it can require non-trivial work to implement alternative analyses, their relative advantages and disadvantages can be empirically explored (Bender 2010). Recently, Fokkens (2011) has been investigating the potential of 'metagrammar engineering', or the development of systems that provide not only implemented analyses of varying phenomena, but in fact multiple analyses per variant. Fokkens argues that this will alleviate the risks of implemented grammars being shaped by the order in which phenomena are analyzed.

(11) COLLABORATION: If we value the potential for faster progress when multiple investigators collaborate, we should develop methodologies and tools which support collaboration.[10]

As will be discussed further in section 5, grammar engineering for language documentation is an excellent example of the kind of project that thrives on collaboration, in this case between one or more field linguists and one or more grammar engineers. The grammar engineering work is dependent on the field work and cannot proceed without data collection, transcription and analysis done by the field linguist. At the same time, grammar implementation allows the hypotheses generated by both the field linguist and (eventually) the grammar engineer to be systematically tested against the collected data. Tools which would facilitate this kind of collaboration include those which help field linguists to produce consistent and well-formatted IGT, on the one hand, and those which make the resulting implemented grammar available for interactive inspection (such as web-interfaces to parsing and generation algorithms) on the other.

4.3 GRAMMAR EXPLORATION

(12) EASE OF FINDING: If we value ease and speed of retrieving the information needed, a GD which has a table of contents, an index and full text search is preferable.

Fangorn is an extremely valuable tool for finding information within a treebank, provided that readers know how to formulate the queries they are interested in. We envision embedding pre-formulated search queries within the electronic prose grammar (as links that retrieve additional examples from the database, for example). An annotated index of these queries could be a useful source of information for a linguist seeking to formulate additional queries.

A second question is how to link back to the relevant parts of the grammar from the trees in the treebank. Ideally, each phrase structure rule, lexical rule and lexical type in the implemented grammar would be annotated with the phenomenon or phenomena that it implements. With such annotations, a reader could move from the tree assigned to a particular sentence to the relevant discussions in the prose grammar (Musgrave & Thieberger this volume). The exact means of encoding these annotations is an issue for future work. However, we note here that linking to a particular prose descriptive grammar is probably a more tractable problem than producing a general index of a stand-alone implemented grammar.

[10] Nordhoff provides a different value statement under the heading collaboration: "We value collaboration and the recognition of the respective contributions of the collaborators" (p. 302). We do not disagree with that value statement, but find the one provided in (11) more relevant to the present discussion.

(13) INDIVIDUAL READING HABITS: If we value the individual linguist's decisions as to what research questions could be interesting (Rice 2006:402), a GD should permit the reader to follow his or her own path to explore it and a short path between two related phenomena is better.

(14) MANIPULATION: If we value portability and reusability of the data, the data presented in a GD should be easy to extract and manipulate.

The key issue regarding individual reading habits, according to Nordhoff (2008), is that some readers will be asking how a particular function is realized within a language, while others will be interested in the function(s) associated with a particular form. In this context, the fact that Redwoods-style treebanks (as described here) include semantic representations is a key asset. While at present, Fangorn only applies over syntactic structures, it can conceivably be extended to searches over semantic structures as well as combined syntactic/semantic queries.

Furthermore, if the implemented grammar is made available along with the treebank, it, too, becomes a tool for both form- and function-based exploration, greatly enhancing the ways that the data can be manipulated. For form-based exploration, the reader can send strings to the grammar for parsing.[11] For function-based exploration, the reader would want to use a generation algorithm (e.g., that included with the LKB (Carroll et al. 1999)). Generation algorithms that work with Grammar Matrix-derived grammars take as input Minimal Recursion Semantics representations (Copestake et al. 2005), which cannot easily be written by hand. However, the Grammar Matrix is compatible with the LOGON machine translation (MT) infrastructure (Lønning et al. 2004). While it would take additional work to produce an MT system (notably the writing of a transfer grammar), this could in principle be done. In that case, within the coverage of the MT system, readers could submit sentences in the other language of the MT pair and retrieve strings in the language being documented. The trees associated with those strings could then point into the descriptive grammar (as above).[12]

(15) FAMILIARITY: If we value ease of access, a GD that is similar to other GDs known to the reader is better.

Here we must acknowledge that treebanks and implemented grammars will not be immediately familiar to linguists on first encounter, and there is work to be done to make them more accessible. However, once a linguist has become familiar with one such resource, that familiarity should be readily transferable to another one constructed in a similar fashion. This once again underscores the importance of tools in promoting standardization (cf. (9)).

(16) GUIDING: If we value an informed presentation of the data, the GD should present the data in a didactically preferred way (Rice 2006:401).

[11] The grammar will return multiple analyses in many cases, but if a parse selection algorithm is trained on the treebank, those analyses can be ranked by their predicted likelihood.

[12] Note that for QUALITY ASSESSMENT (19) and ACCOUNTABILITY (5), strings returned by the generator would need to be flagged according to whether they match strings in the collected data or in fact represent generalizations based on the hypotheses encoded in the grammar.

(17) EASE OF EXHAUSTIVE PERCEPTION: If we value the quest for comprehensive knowledge of a language (Cristofaro 2006:162), the readers should be able to know that they have read every page of the grammar.

Implemented grammars are intricate objects (full of interconnections) and the field of grammar engineering is still struggling with developing best practices for documenting them. It is unlikely that a treebank or implemented grammar would assist in the ordering of information or the creation of paths through a prose descriptive grammar or with ease of exhaustive perception. However, by embedding links to Fangorn in that grammar, the prose descriptive grammar could become a very effective guide to the implemented grammar (to the extent that the analyses in the implemented grammar all directly map to analyses in the prose grammar).

(18) RELATIVE IMPORTANCE: If we value the allocation of scarce resources of time to primary areas of interest, the relative importance of a phenomenon for (a) the language and (b) language typology should be retrievable (Zaefferer 1998:2, Noonan 2006:355).

There are of course many different ways of defining importance of phenomena. If one takes a quantitative approach, a treebank can be a useful tool in exploring such things. Assuming we have an index linking grammar rules and lexical entries to phenomena described in the prose grammar, it should be possible to quantify the text frequency of each phenomenon. Likewise, the number of rules/entries in the grammar which are indexed to the phenomenon would give a sense of the degree to which that phenomenon interacts with others.

Regarding cross-linguistic relevance, in the long term, the Grammar Matrix project has the potential to provide this information: If there are many grammars constructed on the basis of the Grammar Matrix and its libraries (the "customization system"), we will be able to quantify the relative prevalence of each choice in each library, as well as co-occurrence tendencies between the choices. In addition, it is in principle possible to detect whether specific analyses in an implemented grammar remain consistent with the starting point provided by the Grammar Matrix or required changes.[13]

(19) QUALITY ASSESSMENT: If we value indication of the reliability of analyses, the quality of a linguistic description should be indicated.

The development of an implemented grammar is a fairly stringent test of the quality of linguistic analyses.[14] It is not of course the case that implemented analyses are necessarily correct. However, with implemented analyses it is possible to tell whether analyses of multiple phenomena are consistent with each other and also the extent to which the analyses collectively account for the available data (cf. Good's concept of *internal coverage* (this volume)). That is, the quality of a treebank and its underlying implemented grammar can

[13] Of course, there is also always the influence of the grammar engineer (cf. CREATIVITY (10) above): a grammar could differ from the analyses provided by the Grammar Matrix because those analyses did not work for the language in question, or because the grammar engineer chose to explore alternatives.

[14] See also Maxwell (this volume)

be partially assessed in terms of the number of examples in the underlying database which are assigned a tree.

In order for this assessment to reflect on the prose descriptive grammar which is the basis of the implemented grammar, at least two points need to be made explicit: (1) the extent to which the analyses in the implemented grammar are faithful to the descriptive grammar, and (2) the extent to which the implemented grammar incorporates all of the analyses in the descriptive grammar. That is, the descriptive grammar could be very comprehensive, but if the implemented grammar does not include analyses for every phenomenon treated in the descriptive grammar, treebank coverage will be poor.

Using treebanks to assess the quality of individual analyses is somewhat more problematic. The same indexing of implemented grammars that was suggested for measuring the relevance or importance of particular phenomena could also be used to estimate the success of their analysis in implemented grammar. However, these two factors are confounded: A highly central or important phenomenon with a poor analysis would appear to be relatively unimportant, since the poor analysis could lead to poor coverage for the sentences with the phenomenon. Thus what is called for is an independent way to measure the frequency of phenomena (perhaps based on interlinear glossed text alone) and then compare that to the measurements taken over the treebank.

So far this brief discussion has considered grammar/treebank quality only in terms of coverage, or the ability to find a correct analysis for any given example. Another important measure of grammar quality, however, is ambiguity: Grammars or analyses which are underconstrained will produce many spurious analyses. These will not be apparent in the final treebank, as they are discarded in the manual annotation step. However, the maxim in (19) suggests that the degree of ambiguity found by the grammar underlying the treebank should be reported. In addition, it is straightforward to quantify the extent to which particular rules and lexical entries contribute to ambiguity.[15]

Finally, we note that in the development of treebanks for descriptive grammars, the correctness of a tree is determined by comparing the semantic representation associated with that tree to the translation and gloss provided for the example. Thus to the extent that quality issues in the descriptive grammar affect the quality of the glossing, these issues will be masked in measures involving the treebank.

(20) Persistence: If we value citability (Bird & Simons 2003:14), in order to facilitate longterm reference, a grammatical description should not change over time.

As Bird & Simons and Nordhoff note, the solution to the conflict between this maxim and the one in (7) is to take snapshots which can be the anchors for citations. The addition of treebanks to electronic descriptive grammars makes this somewhat more difficult as the versions between the treebank (and implemented grammar) on the one hand and the prose descriptive grammar on the other need to be synchronized. This is perfectly possible, however, with proper planning.

(21) Tangibility: If we value the appreciation of a grammatical description as a comprehensive aesthetic achievement, a GD that can be held in the hand is better.

[15] Note, however, if a particular rule is prone to adding ambiguity, that may not be the fault of the analyses of the phenomena it currently implements (and thus is indexed for) but rather the analysis of some other phenomenon which should involve constraints on that rule but does not.

Implemented grammars and treebanks are only valuable as computational artifacts, and thus will only be the sort of thing that can be held in the hand when hand-held devices are powerful enough to run them. That said, the addition of an implemented grammar should not get in the way of the production of the associated descriptive grammar as book. In practical terms, any links to treebank searches that are embedded in prose chapters should be either stripped or made non-disruptive. In addition, any links in a printed volume must be stable links that will continue to function as long as possible.

(22) MULTILINGUALIZATION: If we value the interest of every human in a given language, especially interest from the speakers of the language in question, a GD should be available in several languages, among others the language of wider communication in the region where the language is spoken (Weber 2006:433).

There are two primary ways in which implemented grammars and treebanks can respond to this maxim. The first is to be designed to be able to incorporate and display glossing of the primary data into multiple different languages. The second (and longer term) method is through the machine translation possibilities discussed in reference to the values INDIVIDUAL READING HABITS (13) and MANIPULATION (14) above. It is possible in principle to set up multiple MT systems between a language being described and different languages of wider communication. Furthermore, while there is additional work required for every language pair, each additional language pair should require less set up work than the first.

4.4 SUMMARY Our purpose in this discussion has been twofold: On the one hand, by reflecting on values and maxims, we have proposed a series of design desiderata for the incorporation of treebanks in electronic descriptive grammars. On the other hand, we hope to have provided arguments in favor of the value of treebanks and implemented grammars to the enterprise of language documentation and description, and clarified the role that they can play.

The incorporation of treebanks into descriptive grammars is possible on the basis of existing technology, including technology supporting grammar development, parsing, generation, treebank creation and maintenance and treebank search. This is sketched in the following section. The preceding discussion makes it clear that achieving the full potential of the integration will rely on further advances in a few areas. These include: methodologies and software support for indexing components of implemented grammars, support for rapid deployment of machine translation, and user interface improvements to make implemented grammars and the analyses they assign to strings more accessible to non-grammar engineer linguists.

5 GETTING THERE In the previous sections, we have presented the idea of augmenting electronic descriptive grammars with treebanks and reflected on how doing so will help descriptive grammars fulfill the values that have been articulated for them. This section addresses the feasibility of creating implemented grammars and treebanks and discusses the resources that are available to assist in the creation of such resources as well as future directions.

5.1 The Grammar Matrix Building implemented grammars can be expensive and time-intensive. The English Resource Grammar (ERG) has been under development since 1994, and now achieves 62-94% verified coverage over naturally occurring corpora from a variety of genres (Flickinger 2011).[16] The example of the ERG shows that this kind of grammar and treebank construction is indeed possible, but it also suggests that it might be too expensive to be applied in context of language documentation, as envisioned here.

We contend that it is not, for several reasons. First, a grammar does not have to be comprehensive, or even approach the ERG's level of coverage, in order to be useful. Even a partial treebank would begin to yield benefits for linguists searching for examples (though it will be important to make clear the extent to which the treebank covers the total corpus, cf. quality assessment (19) above). Secondly, it is unfortunately the case that language documentation projects rarely approach a range of genre diversity in the data collected that compares to the range of genres the ERG has been tested against. A smaller genre range means a more tractable problem for grammar engineering. Finally, much of the effort that has gone into the ERG represents solutions to problems that are not in fact English-specific, but more general contributions to efficient, implemented hpsg parsing.

This last point is the motivation for the LinGO Grammar Matrix (Bender et al. 2002, 2010). Specifically, the Grammar Matrix aims to facilitate the development of implemented grammars in languages without such resources by curating and making available advances from the ERG and other broad-coverage grammars developed in the DELPH-IN[17] consortium, most notably the Jacy Japanese grammar (Siegel & Bender 2002) and the German grammar (Müller & Kasper 2000). The Grammar Matrix consists of a core grammar, shared by all language-specific grammars derived from it, a series of libraries of analyses of cross-linguistically variable phenomena, and a "customization system" which allows users to select from among those analyses by filling in a web-based questionnaire (cf Black & Black this volume).

The core grammar includes definitions (constraints) that are hypothesized to be cross-linguistically useful. The customization system pairs these with more specialized constraints on the basis of information collected through the questionnaire. The questionnaire elicits from a linguist-user typological information of varying granularity: for example, major constituent word order (including various flexible word order options), the means of expression of negation, the range of cases (if any) marked on core arguments, the possibility of dropping each core argument and information about its interpretation when dropped. It also allows users to define classes of lexical items and morphological rules. Morphological rule definitions include morpheme forms,[18] morphosyntactic and morphosemantic features (case, tense, etc.) associated with the morphemes, and ordering and co-occurrence constraints with other morphemes (including stems).

This strategy of code reuse necessarily involves taking analyses developed on the basis of well-studied languages and applying them to lesser-studied languages. However, the

[16] The low end of that spectrum relates to fairly technical corpora, including technical manuals and chemistry papers. Verified coverage over 80% is more typical.

[17] http://www.delph-in.net/

[18] These are expected to be regularized underlying forms. We follow Bender & Good (2005) in advocating for separate components for morphophonological and morphosyntactic analysis. Various tools exist for creating morphophonological analyzers, including XFST (Beesley & Karttunen 2003).

Grammar Matrix project is explicitly data-oriented in its approach to cross-linguistic universals and cross-linguistic variation. With regards to the constraints provided in the core grammar, these are treated as working hypotheses only, ready to be revised (or more precisely made variable and moved into the libraries) when we encounter languages which present counter-examples. The methodology of grammar engineering allows us to empirically test the applicability of analyses and determine when an analysis really won't work. Furthermore, our library development methodology begins with a review of the typological literature so that we are working with the most comprehensive possible view of the range of variation in the world's languages as we develop the libraries of analyses.

The work on Wambaya cited above (Bender 2008a) provides a case-study in the feasibility of grammar engineering for language documentation. The grammar produced is approximately an order of magnitude less complex than the English Resource Grammar. Nonetheless, it provided interesting coverage over both the exemplars cited in Nordlinger (1998) and a naturally occurring text used to test the grammar's ability to generalize beyond the data used in grammar development. It was possible to achieve this level of coverage so rapidly thanks in part to the restricted range of data being considered (relatively short sentences, relatively little genre variation) but more importantly thanks to the analytical work done by Nordlinger. It is in some ways easier to implement analyses presented in a descriptive grammar than to work from intuitions about one's own language combined with analyses gleaned from the theoretical linguistic literature. In other words: the original descriptive work (done in this case by Nordlinger) is the hard part. When this is done thoroughly and done well, the grammar engineering is relatively straightforward.

5.2 Treebanking Support Once an initial version of an implemented grammar has been written, building an *undisambiguated* treebank is an automatic process that can be easily initiated using the suite of tools available. Treebanking, the process of selecting the most plausible tree using discriminants (see Section 2.2), requires further effort, but much less than manually annotating the data. While treebanking will always require a human annotator if we wish to maintain quality, there is some work on automatic methods to help make treebanking easier. One method that has proved successful in previous experiments is to rank the discriminants so as to present those most likely for an annotator to select at the top of the list. Zhang & Kordoni (2010) showed that treebanking speed could be improved by using the annotation logs of their treebankers to build a statistical model that ranked the discriminants in the order which an individual treebanker would be likely to select them. Another method, called blazing (Tanaka et al. 2005, MacKinlay et al. 2011), uses supplementary information available about the text to partially pre-annotate. In this work, the authors used pre-existing annotations of parts of speech (in the case of Tanaka et al. 2005) or phrase structure trees (in the case of MacKinlay et al. 2011) to automatically mark some discriminants, leaving the annotator less decisions to make, and also found increases in treebanking speed. Rather than requiring external information, a third strategy would be to use all the analyses produced for all items to learn trends in the analyses. While this information is noisy, the trends from the less ambiguous items inform the decisions to be made for the more ambiguous items and this partial information can be used to automatically learn a probabilistic ranking function to rank all analyses. In this way, we can prune improbable analyses and in the process accelerate treebanking (Dridan & Baldwin 2010).

5.3 Future Work on Fangorn At present, Fangorn has a query language that is sufficient to express simple queries using paths and filter expressions. However, for more complicated queries with multiple logical operators in a filter expression, allowing braces to group terms would make queries more expressive. For example, let us consider query (3) and add further conditions that require the search to match only those parses where the complement of the verb is realized only by a modifier and not by a nominal head. We would now have to exclude trees which have a HEAD-COMP-2 or COMP-HEAD-2 label underneath the declarative clause. Query (3) would have to be reframed as shown in (23). If the grouping of elements, using braces, were allowed we could rewrite (23) as (24), which is not only more concise, but is also easier to read.

(23) //DECL[//HEAD-COMP-MOD-2 AND NOT //HEAD-COMP-2 AND NOT //COMP-HEAD-2 OR //COMP-HEAD-MOD-2 AND NOT //HEAD-COMP-2 AND NOT //COMP-HEAD-2]

(24) //DECL[(//HEAD-COMP-MOD-2 OR //COMP-HEAD-MOD-2) AND NOT (//HEAD-COMP-2 OR //COMP-HEAD-2)]

Another potential means of grouping terms within a filter expression would be to take advantage of the types declared in the grammar behind the treebank, which group together sets of rules. For instance, there are grammar types in Wambaya grammar, shown in (25) (cf. Figure 3), that match the two elements of the filter expression in (24). Replacing elements in (24) with their grammar type would allow us to further refine the query to (26). The search tool could itself perform the substitution of grammar types with actual labels rather than expect the user to input expanded queries. For this to work, Fangorn has to be aware of grammar types and expand them prior to execution.

(25) head-2nd-comp-mod-phrase:
{ head-comp-mod-2, comp-head-mod-2 }
wmb-head-2nd-comp-phrase:
{ head-comp-2, comp-head-2 }

(26) //DECL[(//HEAD-2ND-COMP-MOD-PHRASE AND NOT //WMB-HEAD-COMP-2ND-COMP-PHRASE]

The current version of Fangorn operates over the abbreviated tree structures that are used for presentation purposes. The abbreviated trees are sufficient to distinguish between competing analyses, but they don't expose all the information that a user might wish to search for. As mentioned in Section 4.3, the semantic information embedded in the tree would provide a useful mode of querying. This provides some interesting challenges in determining the best way to represent semantic information so that it can be queried, since a tree structure is not a natural representation for semantics. We are currently pursuing two different approaches to this problem: either trying to find a natural way to represent the semantic information we have in a treelike form, or alternatively, looking for an intuitive extension of the query language that would allow querying over a more appropriate representation.

Being able to query the syntax and semantics separately provides different views and avenues of access to the same data. Likewise, other levels of annotation that exist, such

as glosses and translations, could be useful in finding the examples that a user requires. A simple extension to Fangorn is planned to allow different annotation levels to be aligned, so that it is possible to search using one representation and see how the same data is analyzed at a different level. A more complex extension would allow a query to filter using multiple levels of annotation, for example using semantic restrictions to filter a syntactic query. This extension could require extensive changes to the query language for a fully general solution, but it might be possible to achieve most of the desired capabilities by designing a means of specifying metadata about annotations both within the treebank and in the query language.

Another area of future work for Fangorn is the mapping of labels onto a cross-linguistic label set, e.g. based on GOLD (Farrar & Lewis 2007). This would involve aligning individual grammar rules, lexical rules and lexical types onto the GOLD ontology to mark features such as verb transitivity, noun case and clause illocutionary force, while preserving the language-specific rule types and/or more familiar node labels (e.g., NP and VP) as are currently used. This would significantly enhance cross-linguistic treebank search, as the label set would be harmonized to a much greater extent than occurs using the "native" label set for individual grammars.

5.4 **Virtuous Cycles and the Montage Vision** The Wambaya case study described above was an exercise in post-hoc grammar engineering: The implemented grammar wasn't developed until a decade after the original field work was complete, and sadly, the language lost its last fully fluent speakers in that time. The process of grammar engineering always raises further questions about the data (as no grammatical description is ever complete), and the Wambaya case study suggests that collaborations between grammar engineers and field linguists could be very fruitful:[19] While a considerable amount of data collection and analysis has to take place before grammar engineering can get off the ground, if the field linguist is still working with speakers when the grammar implementation work begins, there is the potential for a feedback loop that speeds up and strengthens the descriptive work.

The Montage project (Bender et al. 2004) envisioned a software environment which integrated tools for the production of IGT, electronic descriptive grammars and implemented grammars. The IGT and the descriptive grammar would inform the implemented grammar, and even possibly be input to a system that could automatically create a partial implemented grammar. The implemented grammar would in turn feed IGT and descriptive grammar development by locating interesting exemplars (through Fangorn[20]), highlighting possible inconsistencies in glossing, and testing out analyses.

The Montage project itself was never funded, but nonetheless there is progress in the direction of this vision, including:

[19] We would like to emphasize that nothing in the preceding discussion requires that the grammar engineering and field work be done by the same person, and in fact it seems unlikely that many people would have the skill sets required for both. Going further, it seems like grammar engineering would be a less than efficient use of the time of someone who has the skills to do original fieldwork.

[20] Note that this could even be done before the manual annotation step of the treebank construction process: the treebank search tools described above work equally with undisambiguated sets of trees.

- Collaborative annotation and descriptive grammar authoring environments, including GALOES (Nordhoff 2007), TypeCraft (Beermann & Mihaylov 2009) and Digital Grammar (Drude, this volume)
- The Grammar Matrix customization system (Bender et al. 2010, cf. section 5.1)
- The Redwoods methodology for dynamic treebank construction (Oepen et al. 2004, cf. Section 2.2)
- Treebank search using Fangorn (Ghodke & Bird 2010, cf. section 3.1)
- Machine learning algorithms that learn typological properties from IGT (e.g., Lewis & Xia 2007)

The Grammar Matrix makes it feasible to create interesting implemented grammars for languages without large computational resources, while the Redwoods methodology makes treebank development practical. Fangorn makes the treebanks useful as resources for readers of descriptive grammars. The longer term goal of semi-automatic grammar implementation is supported by the Grammar Matrix and the work of Lewis & Xia (2007) which suggests that it might be possible to learn answers to questions like those in the Grammar Matrix questionnaire on the basis of (sufficiently large) sets of IGT (with sufficiently meticulous glossing).

6 Conclusion In this paper we have presented a vision of how electronic descriptive grammars can be enriched with implemented grammars and treebanks, and described how such a vision is supported by current technology as well as what future developments could add further value. Following the discursive approach of Bird & Simons (2003) and Nordhoff (2008), we have explored the ways in which implemented grammars and treebanks can help to meet the values and associated maxims proposed regarding producing the most useful possible language resources. To our knowledge, no such treebank-enhanced descriptive grammar yet exists, but we hope to see them emerge through the collaboration of field linguists and grammar engineers.

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Electronic Grammars and Reproducible Research

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It is time for grammatical descriptions to become reproducible research. In order for this to happen, grammar descriptions must be testable, not only by the original author, but also by other linguists. Given the complexity of natural language grammars, and the ambiguity of prose descriptions, that testing is best done using computational tools to verify a computationally implementable grammar. At the same time, grammars need to be useful—and testable—for the foreseeable future; that is, they must be archivable. Yet if a computational grammar is tied to particular computational tools, it will inevitably become obsolescent. This paper describes a means of creating computationally interpretable grammars which are *not* tied to particular computational tools, nor (to the extent possible) to any particular linguistic theory, and which can therefore be expected to remain useful into the future. In order to make such formal grammars simultaneously understandable to humans, they are embedded into descriptive grammars of a more traditional sort, using the technique of Literate Programming. The implementation of this technology for morphology and phonology is described. It has been used to create morphological grammars for Bangla, Urdu and Pashto which are both human-readable and computationally testable.

1 What can be new about grammars?

> An article about computational science in a scientific publication is not the scholarship itself, it is merely advertising of the scholarship. The actual scholarship is the complete software development environment and the complete set of instructions which generated the figures. (Buckheit & Donoho 1995)

Of all the methods for documenting and describing languages—the creation of written corpora for linguistic purposes, lexicography, grammatical description, and audio and video collection—it is grammar writing that has the longest history. Grammars of Sanskrit, Tamil, ancient Greek, and Latin date back thousands of years.[1] Oddly, the method for writing grammars has changed little; the invention of glossed interlinear text has been perhaps the

[1] This material is based upon work supported, in whole or in part, with funding from the United States Government. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author, and do not necessarily reflect the views of the University of Maryland, College Park and/or any agency or entity of the United States Government.

most noticeable advance. Even the advent of the computer age, which revolutionized lexicography and corpus creation, and made audio and video documentation practical for the first time, has not significantly changed the nature of grammars. For the most part, grammars continue to be a catalog of the various constructs of the language: noun formation, noun inflection, the order of words in the noun phrase, and so forth, augmented by examples, generally from corpora. All this could be done just as well on paper as on a computer.

It is true that grammar writing has become easier. Grammar authors can draw from the entire set of characters encoded in Unicode, something which was painfully difficult in the era of typewriters, and often inaccurate when typeset by someone unfamiliar with the language. Modern grammar writers are also blessed with the ability to find examples more easily now that the corpora are on computers; and often these corpora are already stored as interlinear text. Whether the interlinearization has been done consistently has not always been easy to verify, even when the interlinearization was done on computers. But even this is becoming better; SIL's Toolbox has an "Interlinear Verify" mode, which flags annotations that don't match lexical entries, and SIL's Fieldworks Language Explorer (FLEx) maintains consistency between the lexicon, grammar, and the interlinear text. Finally, there are now checklists of phenomena to be covered, and often grammars of related languages to draw inspiration from.

While making grammar writing easier is a laudable goal, I believe that a more significant step would be for the resulting grammatical descriptions themselves to change: grammars as language descriptions[2] must become instances of reproducible research. That is, it must be possible for the reader—indeed, for future generations of linguists—to verify that the grammar is correct, i.e. that it actually describes the language as its author claims.

One significant step towards this goal has been what I will call "write-time" links: links from the examples in the grammar to the location in an electronic corpus from which the author copied them (Nordhoff 2008, Thieberger 2009). This allows the reader to view the author's example in context. Indeed, it should be possible to have links to the point in the original audio or video from which the example was transcribed, in principle allowing the grammar user to verify the transcription as well.

Going beyond these author-provided "write-time" links to examples, a further step towards reproducible research would be to enable search for grammatical constructions at "read-time," i.e. when the user is reading the grammar. To my knowledge, this innovation has yet to be implemented. It would require either annotation of a fixed corpus for all the grammatical constructs described in the grammar, or else an on-the-fly grammatical analysis and search facility (Musgrave & Thieberger this volume). The latter method would be superior, since it does not depend on the authors' bias as encoded in the annotated corpus. Furthermore, it would allow searching for grammatical constructions not only over the corpora provided with the grammar, but over any additional corpora that the reader may have access to.

[2] An anonymous reviewer has pointed out that there are other sorts of grammars besides rule-based descriptions, including studies of the historical development of grammatical features, typological comparisons, analyses intended to explicate or improve the coverage of a particular theory, and comparative grammatical studies across related languages. In contrast, this paper discusses the grammatical description of a single language, with emphasis on observational adequacy.

Several requirements must be met in order to do read-time grammatical search over an arbitrary corpus:

1. For languages with significant inflectional morphology, there must be a morphological parsing engine.
2. If the grammar describes syntax, a syntactic parsing engine will also be necessary.
3. The grammar must be represented in a way in which it can be used by the parsing engine(s).
4. There must also be a lexicon compatible with the grammar. Specifically, the grammar and lexicon must use interoperable coding for parts of speech, conjugation or declension classes, etc.
5. A tokenizer must be available, to convert the text into tokens which a parser can deal with. There may also be a need for lower-casing words in scripts that make case distinctions.
6. The corpus must be encoded in the same way as the grammar and lexicon, and use the same writing system (or else it must be possible to convert between encodings and writing systems).
7. Finally, the reader will need a tool which can search through the structures output by the parser.

There are also problems of ambiguity resolution; parsers can be expected to frequently return multiple parses (cf Bender et al. this volume). Indeed, even tokenization may be ambiguous.

While "read time" search for grammatical constructions is not, to my knowledge, currently possible, I believe it is a desirable goal, for without it the reader is forced to accept at face value the author's description of the language; there is no way to verify the grammar.

This paper describes some steps towards this goal. But first, a discussion of why this goal is important.

2 Archivable research Bird & Simons (2003) drew the attention of linguists to the need for language documentation and descriptions to be archivable. They argued that digital copies of lexicons and texts should be preserved in plain text formats, as opposed to binary formats (such as proprietary database or word processor formats); and in particular, they advocated the use of XML and Unicode. While Bird and Simons said little about how to make grammars archivable, much the same case could be made for descriptive grammars: preservation in XML/Unicode formats is preferable to archiving them in proprietary word processor formats.

But there is more to be said about grammars. Since at least the 1980s, it has been possible to write grammars in computer-readable format, such that the rules could be turned into a parser and applied to texts. For example, SIL released the AMPLE parsing engine[3] (Weber et al. 1988), which has subsequently been used to create morphological parsers for

[3] I make a distinction between a generic *parsing engine*, which may be suitable for grammars of a wide range of languages, and a *parser*, which is the application of a parsing engine to a particular language. Parsers are

many minority languages; other morphological and syntactic parsing engines have become available since then. Bird and Simons did not touch on how (or whether) computer-readable grammar rules for such parsers should be preserved. However, Amith & Maxwell (2005), Maxwell & Amith (2005) and Maxwell & David (2008) discuss the following problem: while we can preserve the grammar rules that could be used by this or that parsing engine, the parsing engines themselves—like any software—will eventually become obsolete. The question then is how computer-readable grammar rules, suitable for parsing corpora, can be archived. In particular, how can we write grammars incorporating such rules in a way that the grammars will be usable long after the original parsing engine has become obsolete?

The work presented here builds on these issues of archivability, but expands on them by considering how making a grammar including computer-interpretable rules archivable also contributes to making such a grammar an instance of reproducible research. I now turn to that issue.

3 Reproducible research

> Abandoning the habit of secrecy in favor of process transparency and peer review was the crucial step by which alchemy became chemistry (Raymond 2004).

A fundamental requirement of modern scientific research is that the results be reproducible. This can of course mean different things in different sciences; for medical research, it generally means that the application of a treatment to a different group of patients will lead to similar statistical results. But in sciences like astronomy, where an event like a nearby supernova may not be repeated for centuries, it means being able to reproduce analyses from an archived set of data. Language description has elements of both of these kinds of research. For many languages, it is possible to collect additional data, which may be used as additional test cases to confirm or refute a grammatical analysis. But it may be difficult to collect new data from "exotic" languages, and impossible with extinct languages, so that reproducibility in such cases means being able to verify that the structures of a fixed corpus can be generated from a lexicon and rules.

In a sense, linguistics has long been about reproducible research. Grammars have included examples, often in the form of interlinear text, presumably intended not only to illustrate the abstract grammar rules, but also to allow the reader to verify the rules. In some cases, text corpora are published together with the grammar; recently, Bahrani et al. (2011) included a small corpus of test sentences they used to evaluate their syntactic parser. But therein lies the problem: while it may be possible to verify a rule, or a small set of rules, on a few cases, verifying all the rules on all the examples of the grammar, or worse on an entire corpus, is beyond the patience or even ability of most of us. Languages and their grammars are simply too complex; and as a result, research in linguistics is all too often not verifiable in practice. Indeed, with rare exceptions (such as D. Payne's 1981 grammar of Axininca Campa), published grammars are not explicit enough to support verification.

In addition to the fact that grammars are often too difficult to test by hand, two other factors make it virtually impossible for traditional descriptive grammars to constitute repro-

usually built from three parts: the generic parsing engine, a language-specific grammar in a format readable by the parsing engine, and a language-specific dictionary, also in a format readable by the parsing engine.

ducible research. First, even the best of grammars generally have gaps in coverage. This is of course true for syntactic grammars, but it is also true for morphological grammars of languages with complex morphology. As Bauer (2010) writes,

> reliance on grammars is not sufficient to give completely accurate data... Descriptive grammars rarely exemplify derivational patterns in any detail, rarely say what is productive and what is not, rarely tell you whether the examples they provide are regular or not, and typically provide lexicalised examples. In other words they do not usually provide precisely the kind of information that the morphologist would like to know about.

Second, the fact that descriptive grammars are themselves written in ordinary languages such as English means that they are inevitably ambiguous. The problem of ambiguity has been discussed for decades in the context of writing specifications for computer programs; see e.g. Abbott (1983), Wiegers (2003), Meyer (1985), Berry & Kamsties (2003), and Kamsties et al. (2003). The situation is no different, in my experience, for grammar writing; grammatical descriptions are unclear and ambiguous in unforeseen and probably unforeseeable ways. Experience by our team of grammarians at the University of Maryland has found many examples of unclear writing, even in the best of grammars, resulting in our needing to determine what is really going on in the language by consulting other grammars, talking with other linguists working on the languages, and doing our own fieldwork and corpus research. These problems will not go away by trying to write more clearly. The fact that natural language is not sufficiently clear and unambiguous is one of the reasons that natural languages are not, despite years of trying, used for programming computers. Rather, making grammar writing truly reproducible requires that we have an unambiguous way of expressing grammar rules and constraints: a formal grammar, analogous to a computer programming language.

For these same reasons, in many scientific fields the term "reproducible research" has come to mean something like the following :

1. Publication of an analysis in more or less the usual form, such as an article in a journal or conference proceedings.
2. Publication of the data used in the analysis in downloadable form.
3. Publication of the software used to perform the analysis in downloadable form.

This form of reproducible research thus differs from simply data archiving in that not only the data, but the software used for analysis, is made available to other researchers. The analysis described in natural language provides an easily read view of what the authors did, but the published software and data provide the final complete and unambiguous description with which their claims can be verified.

Reproducible research of this sort is often documented by using Literate Programming (Knuth 1992) to produce a "compendium," a computer-readable version of the document combining a textual description for human consumption with the software program for computer consumption (Gentleman & Lang 2004); that is, parts (1) and (3) above, and sometimes the data (part 2). This compendium can be obtained by other researchers, who can

extract software for verification against data, whether data contained in the compendium, or other relevant data.

In the Literate Programming paradigm, the ordinary published paper (item (1) in the above list) can be produced as a readable "view" of this compendium document, by an automatic conversion process. In fact, it is possible to produce multiple print views from the same compendium; a standard print view might include the program code used to analyze the data, while a view for publication in a conference proceedings might omit this code because of page limitations.

Literate Programming has been used to publish reproducible research in geophysics (Claerbout & Karrenbach 1992), bioinformatics (Gentleman & Lang 2004, Hothorn & Leisch 2011), epidemiology (Peng & Zeger 2006), signal processing (Buckheit & Donoho 1995, Vandewalle et al. 2009), statistics (Leisch 2002, Donoho et al. 2009, Lenth & Højsgaard 2011), econometrics (Koenker & Zeileis 2009), and other fields.

Moving in this direction, as of 2011 National Science Foundation grant proposals must include a data management plan (http://www.nsf.gov/pubs/policydocs/pappguide/nsf11001/gpg_2.jsp#dmp). While this addresses the availability of the data leading to an analysis, it does not attain the full goal of reproducible research. Specifically, it does not require publishing the computational methods used to process the data. Some journals have accordingly gone further, encouraging authors to submit their articles as true reproducible research using Literate Programming: the *Annals of Internal Medicine* (Laine et al. 2007); *Biostatistics* (Peng 2009); *The Insight Journal* (see http://www.insight-journal.org/); *Computing in Science and Engineering* (Fomel & Claerbout 2009); and *IEEE Transactions on Signal Processing* (see http://www.signalprocessingsociety.org/publications/periodicals/tsp/). The publisher Elsevier has sponsored the "Executable Paper Grand Challenge" at the The International Conference on Computational Science in Singapore in June 2011. For linguistics, the new *Journal of Experimental Linguistics* (http://www.elanguage.net/journals/index.php/jel/index), part of the LSA's eLanguage initiative, could begin to address these issues.

At the University of Maryland, we have begun using Literate Programming to document grammars of natural languages, particularly the morphology and phonology of these languages, as reproducible research. As with other Literate Programming approaches, our grammars consist of two interwoven parts: one is a traditional descriptive grammar, complete with interlinear examples; the other, a formal grammar, is intended for use together with a lexicon as a morphological parser. Our approach differs from that of most previous work in Literate Programming in that our formal grammar is not written in the programming language of some existing piece of software. Rather, our formal grammar is a structured XML description of the grammar. Creating a parser in order to verify the grammar against a set of examples or a corpus thus requires an additional step: converting the XML description into the programming language of a suitable parsing engine. We have added this step because of the importance in linguistics of archivability: it safeguards our formal grammar against the inevitable obsolescence of the parsing engine, a point to which we return later in this paper.

4 Producible research

> The tale of the Zigglebottom Tagger is one of disappointment, not just for you but also for Zigglebottom himself. While his work achieved publication, it

> must gnaw at his scientific conscience that he can't reproduce his own results (Pedersen 2008).

For the reasons outlined above, I believe reproducible results should be a clear requirement in the field of linguistics, and for grammar descriptions in particular. But before a result can be reproducible, it must be producible—that is, it must be possible for the researchers to verify their own results. Sadly, that is not true of many grammars. When a grammar has any significant degree of complexity, it is too difficult and time-consuming to test every grammar rule on every form in a corpus, keeping in mind every constraint on rule application provided by the theory. Instead, grammar writers generally test their rules (or perhaps only the rules which they expect to be relevant) to selected test cases.

This happens for rule-based grammars (which are the focus of this paper), but the problem is at least as bad with constraint-based systems like OT: there are too many active constraints, and too many possible forms (infinitely many, in most OT theories) to determine the correct answer by hand in any but a small set of test cases. Lauri Karttunen makes this point clearly, speaking of OT: "Paper-and-pencil methods are insufficient to test a theory with real data" (2006: 287).

This is not to say that there are not grammars which are relatively simple, and which could therefore be tested by hand. The inflectional morphology of English, for example, is not hard to test; and purely agglutinating morphologies, with little or no allomorphy, are often testable by hand. But when significant morphology interacts with significant phonology to create significant allomorphy, it is all too easy to overlook rule interactions, with the probable result that not all forms in the corpus can in fact be derived by the proposed grammar. Syntax is, of course, still more complex, and it is correspondingly more difficult to determine whether a syntactic grammar accounts for a corpus.

As Pedersen (2008) suggests with his tongue-in-cheek description of the "Zigglebottom Tagger" quoted above, failure of other researchers to reproduce published results may cause the author to question whether the results were correct in the first place. The methodology described in this paper thus provides a way for other linguists to not only reproduce, and thereby verify, grammatical descriptions, but for the author to validate the grammar in the first place, in as much detail, and with as many test cases as desired.

Some readers may be asking whether the problem is really as bad as I am painting it. Surely most grammars are explicit enough that the authors, at least, have validated them, and that other linguists could in principle validate them? It is impractical to answer this for all grammars, so I will instead supply some examples from my personal experiences in grammar writing.

I first encountered the difficulty of telling whether my own grammatical analysis covered the data when I co-authored a grammar of Cubeo, an agglutinating Tucanoan language (Morse & Maxwell 1999). The difficulties in verifying the analysis had to do with both morphology and syntax. I could check a few example sentences for conformance to the generalizations my co-author and I made, but it was beyond us to check all the examples for conformance to all the grammar rules. Indeed, after the published grammar appeared, I realized that my analysis failed to correctly generate some of the cells in the verb paradigm. I am afraid to find out what other errors might surface if I wrote a Cubeo parser and tested it against a corpus, or even against the examples in the book.

My suspicion of how hard it was to verify a grammar against a corpus was confirmed a few years later, when I worked with Jonathan Amith on the Oapan dialect of Nahuatl. My task was to write a morphological parser, using the Xerox finite state toolkit (`xfst`, see Beesley & Karttunen (2003)). This dialect of Nahuatl combines the polysynthetic nature of all varieties of Nahuatl with a particularly messy set of phonological processes. Our analysis has more than 30 rules to derive verb stem allomorphs, which interact in complex ways with aspectual marking and with lexically defined allomorphy classes, plus another 30-odd general phonological rules; many of these rules are crucially ordered with respect to each other. This last problem—that of determining rule ordering—was particularly problematic, as it was not always obvious whether two rules could interact, and crucial cases often did not appear until months after we had written the two rules. When we encountered an erroneous form, we had to debug the grammar in order to discover where the error came from: it might be because we had written one of the rules incorrectly, or because the rules were incorrectly ordered.[4] The cause was almost never apparent from inspection, and the only way to discover it was to temporarily remove rules which might be interfering, or to modify rules, or to re-order the rules until the correct form was produced. Occasionally it was necessary to inspect intermediate forms. It would have been helpful to automatically produce a trace of the rule application (a derivation), although that happens not to be straightforward in the `xfst` tool. While this may seem bad enough, it was not always the case that our first repair was right: sometimes fixing the rule for one form would cause other previously correct analyses to fail.

Almost none of these problems could be found by inspection; we only knew about them when we ran the parser over all our test data and compared the results with previous results, to look for unanticipated changes.[5] Even when we knew there was a problem, it was often unclear what rule or rules caused the problem, how to fix it, or what the implications of a fix would be across the grammar and lexicon. In summary, it was generally impossible to tell by inspection whether an analysis covered all the data in the corpus.

It is important to say that these problems in converting a descriptive grammar into a parser do not constitute a criticism of Amith's grammar writing ability (or, I hope, of my ability to understand descriptive grammars). Rather, this need for clarification, disambiguation and testing happens whenever humans write complex descriptions. In summary, the capability of building a parser based on one's grammar and a lexicon, and testing this against the examples of the grammar and against a corpus, is the only way to verify that one's own grammar works.

Having discussed the problems of making grammatical analysis archivable, reproducible and producible, I now turn to our solution, consisting of three parts: a descriptive grammar, a formal grammar, and a way of testing the grammar against real data.

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[4] We might also have chosen the wrong underlying form of a morpheme; but that seems to have been less of a problem in our case.

[5] In software development, this is called "regression testing," and it is supported by an array of tools, including version control systems and 'diff' (for "difference") tools. The writing of linguistically motivated computational grammars is highly dependent on such software development tools.

5 Descriptive grammar

> Literate programming has many adherents, but it failed to become mainstream programming technology. Partly, we believe, this is due to many programmers' aversion to writing documentation in any form. But we in the mechanical theorem proving community do not have the luxury of avoiding documentation. For one thing, proofs are often much more complex than programs; many of us prove theorems about programs. (Gamboa 2003)

Like researchers in theorem proving, linguists have a long history of documenting the grammars of languages: traditional descriptive grammars are entirely documentation, and the descriptive grammars we have been writing at the University of Maryland are not much different. In order to make them more likely to be useable in the long run, and therefore meet the needs of archiving, in our grammar writing we avoid binary formats and instead use a well-documented XML-based standard, DocBook (Walsh & Hamilton 2011). DocBook was designed for technical documentation, particularly computer documentation. As such, its schema (the configuration document that describes what a valid DocBook document is) has provision for many constructs which are needed to describe software, but which are irrelevant to language description. While these may be simply ignored, it is easy enough to customize the schema to omit the unneeded constructs, thereby ensuring that they are not inserted accidentally.[6]

As an alternative to DocBook, we could have used some subset of the TEI document encoding (http://www.tei-c.org/Guidelines/P5/). We have no strong opinions on the merits of DocBook vs. TEI; our decision was based on familiarity with DocBook, and the availability of tools that made it easier to use. Porting descriptive grammars from DocBook to the TEI format should not be difficult.[7]

Descriptive grammars typically make use of a few specialized constructs, such as interlinear text. We have therefore enriched the DocBook schema to allow not only for glossed interlinear examples,[8] but also for inline examples. The latter are one or two word examples, typically in the main text or in paradigm tables. Because we tag interlinear and inline examples as XML elements, they can be automatically extracted as test cases for the parser. This is an essential aspect of ensuring that our grammars are reproducible. If we relied on a traditional corpus alone for parser testing, we could not ensure that the parser covered all paradigm cells in all paradigm classes, because the corpus might lack rare forms, such as vocatives. But if we have sample paradigms for all declensions or conjugations, stem

[6] There is a project to produce a simplified DocBook (http://www.docbook.org/schemas/simplified), omitting many of these specialized constructs. However, as I write this, it is only available in a DTD form, which was used with DocBook version 4; DocBook version 5, which we are using, uses a RelaxNG schema (see http://www.relaxng.org/). The DocBook organization is working on a simplified schema corresponding to version 5, which may be published by the time this paper reaches press. The DocBook Publishers Schema (http://docs.oasis-open.org/docbook/specs/publishers-1.0-spec-cd-01.html) is similar in intent to Simplified DocBook, and uses a RelaxNG schema. Our modified schema is substantially similar to the DocBook Publishers Schema, modulo the additions we have made for linguistic data.

[7] Another alternative for the descriptive grammar might be the NLM (National Laboratory of Medicine) "NCBI Book Tag Set", see http://dtd.nlm.nih.gov/book/.

[8] Our XML schema for interlinear text and the style sheet for displaying it were simplified from code made available by Andy Black, of SIL, which he had developed for his own grammar documentation project. See also Hughes & Bow (2003) for a general model of interlinear text.

allomorph classes,[9] and irregular (suppletive) words, then we ensure that we have at least one test case for each paradigm cell of every word class.

While we could simply embed the formal grammar as an appendix to the descriptive grammar, we have followed the usual practice in Literate Programming by breaking the computer-readable program (in our case, the formal grammar described below) into "fragments," and placing these fragments in the relevant places throughout the descriptive grammar. For example, the formal grammar fragment for the affixes of the first noun declension class in Pashto appears in the section of the descriptive grammar describing this class. Supporting this capability required augmenting DocBook by the addition of a couple of elements (modified from Walsh (2002)): one to enclose the fragments of our formal grammar in the descriptive grammar, and one to provide a mechanism to re-unite those fragments in the correct order as a single file suitable for conversion to a parser. (This process of re-uniting the fragments is discussed in the next section.)

In order to produce a typeset grammar from our XML grammar, it is necessary to convert the XML document into some other form. DocBook documents are commonly typeset by conversion to "XSL-FO" (XSL Formatting Object) format, although they can also be converted to Microsoft Word. However, our experience with conversion to Word showed that manual post-editing was necessary, and the need for rapid turn-around (e.g. to make changes near the end of grammar writing) made that impractical. The XSL-FO route did not appear to produce sufficient quality for our multi-lingual work, particularly where non-roman scripts were involved—and all our grammar work thus far has included non-roman scripts (the Bengali script, the Nastaʿliq style of the Arabic script for Urdu and Punjabi, the Naskh form of the Arabic script for Pashto, and soon the Thaana script for Dhivehi). Fortunately, two pieces of the puzzle came together at the right time to solve our problem. Jonathan Kew created the XeTeX program (http://scripts.sil.org/xetex), a Unicode-aware version of the excellent LaTeX typesetting program; and Benoît Guillon created the dblatex program (http://dblatex.sourceforge.net/), allowing for conversion of DocBook documents to LaTeX format. Since dblatex is distributed as open source, modifying it to convert our added constructs was not difficult; and LaTeX (and therefore XeTeX[10]) already has packages for typesetting interlinear text, as well as a host of other useful packages. Together, these pieces of software allow us to produce high quality PDFs of book-sized grammars in a matter of minutes, with no manual intervention.[11]

We also wanted to be able to produce PDFs of our grammars for diverse audiences. For example, someone interested only in using our grammar as a desk reference might not wish to see the formal grammar, but might want explanations of linguistic terms that would be superfluous to a linguist. Also, we occasionally add descriptions of alternative grammatical analyses, such as an explanation for why we chose a particular set of declension classes to describe Pashto (published descriptions of Pashto range from five declension classes to a

[9] Our grammatical formalism distinguishes inflection (declension and conjugation) classes, which refer to the choice of affixes, from stem allomorphy classes. Since stem allomorph classes often cross-cut inflection classes, this represents a useful partitioning of information. There are also theoretical reasons for distinguishing the two notions, see e.g. Carstairs (1987), particularly chapter 6.

[10] Almost all LaTeX packages are usable with XeTeX, and the user community has been most helpful. Most recently, Apostolos Syropoulos modified a package enabling the use of change bars so that it worked in XeTeX—for free!

[11] Software to convert DocBook documents into HTML form is also available.

dozen); these explanations would be of little interest to most non-linguists. For this purpose, DocBook provides an attribute called "audience." For our work, we set this to "tech" on portions of text that we want to hide from a non-technical audience, or "non-tech" for pieces of text to be hidden from a technical audience (and we leave the attribute unmarked on text that is appropriate for both audiences). When we create the PDF, we tell the conversion process to omit the non-relevant portions, giving us output tailored for the particular audience.[12]

6 Formal grammar

> I thought the specifications were precise, but nobody understands how imprecise a specification is until they try to explain it to a computer. And to write the program. (Knuth 1996:608)

Unlike descriptive grammars, the notion of a formal grammar of the sort we are using is relatively new. Our formal grammar is intended to represent much the same information as that conveyed by the descriptive grammar, but in a form that is computer readable—specifically, in a form that can be converted into a parser without human intervention. We had several desiderata for this grammar representation formalism:

1. The formalism should cover a wide range of linguistic constructs.
2. It must be suitable for a typologically wide variety of languages.
3. While designed to be computer-interpretable, it must also be human readable with a modicum of training.[13]
4. It should be, to the extent possible, self-documenting. That is, each piece of language-specific information should be tagged for its function using mnemonic tags.
5. The linguistic theory behind the formalism should be understandable a decade or a century from now.
6. The formalism should work together with other formalisms used for language documentation and description.

The XML-based formalism we developed largely meets the above desiderata, as described below.

6.1 Coverage of linguistic constructs Our formalism covers most morphological and phonological constructs. It does not cover syntax, semantics, or pragmatics; but coverage of morphology and phonology, without syntax, is adequate for the creation of morphological parsers. Indeed, interlinear text glossing typically (and not coincidentally) is done using exactly the same range of markup as our formal grammar covers: very rarely does interlinear text markup include syntactic annotation.

[12] Obviously we could make finer distinctions than "tech" vs. "non-tech" if we wished (Baraby this volume)

[13] In this respect, the grammar formalism resembles a high level programming language such as Python.

Some linguistic objects such as lexicons are already covered by other standards, and the formalism described here is intended to work with those standards, not duplicate them, as described in section 6.6.

Within morphology, the coverage of the formalism includes the following:

- Inflectional and derivational morphology
- Morphosyntactic features
- Exception features (e.g. for stem allomorph classes)
- Prefixes, suffixes, infixes
- Reduplication and other sorts of process affixes
- Position classes for inflectional affixes (inflection can also be modeled without such classes)
- Inflection classes (conjugation and declension classes)
- Compounding, incorporation
- Listed phonologically conditioned allomorphs (for roots, stems, and affixes)
- Listed irregular (suppletive) word forms

In the domain of phonology, the coverage includes the following:

- Phonemes, graphemes, and boundary markers
- Natural (or unnatural) classes, defined as sets of phonemes
- Phonological rules, including epenthesis and deletion rules
- Rules apply in linear sequence.
- Rule strata can be defined.
- Rules can apply simultaneously, or iteratively left-to-right or right-to-left.
- Environments are definable as regular expressions over phonemes, graphemes, boundary markers, natural classes, and strings.
- Phonological rules can be restricted to a particular part of speech.
- Rules can require the presence or absence of an exception feature.

Notice that phonologically conditioned allomorphy can be treated by either listing the allomorphs and their conditioning environments, or by deriving allomorphs from underlying forms using phonological rules. The former is often easier to use for affixes, and indispensable for suppletive allomorphs, while treatment by rule is often easier for stem allomorphy.

As of now, most of the above constructs can be converted for use by the parser; see section 7.

6.2 **Applicability to typologically diverse languages** Initial development of the grammar formalism was done around 2000 under the auspices of SIL International, and in particular with the help of Gary Simons and Andy Black, both members of SIL. The concern was to ensure that to the extent possible, the formalism supported accounts of the morphology and phonology of the world's languages at the observational level of adequacy (in the sense of Chomsky (1965); see further in section 6.5). Much of this work involved searching through publications to ensure that the model we were building covered the sorts of constructions described there. For the most part, these publications were theoretical works on morphology and phonology, particularly handbooks of morphology and phonology, since these served in effect as a distillation of published grammars. The resulting catalog of construction types outlined in the previous section is, we are confident, adequate to cover most of the morphological and phonological constructions found in the grammars of individual languages. However, some limitations will be described below. In particular, over- and under-application of phonological rules in reduplication may be difficult or impossible to describe in this formalism. Also, some linguists may consider the coverage of syllabification and stress assignment to be inadequate.

6.3 **Computer interpretability vs. human understandability** The focus of this paper is on documenting grammars, not on how those grammars are created. Our formal grammars are, at least for now, written by humans; it may become possible to automatically adapt a formal grammar from one language to a closely related language, or to induce formal grammars from bitext, particularly from existing interlinear text (see Lewis et al. (2008) for some ideas along these lines). But regardless of how the grammars are created, we take it as important that they be understandable by humans. At the same time, if the formal grammar is to used to build a parser, then like any programming language it be must be interpretable by the computer without human help.

Furthermore, as words are found which fail to parse (generally by building a parser from the formal grammar and discovering where it fails), it must be possible to find the cause of the problem. Errors can occur in any of several places: the original corpus may be in error (someone may have mistyped a word, for example); the lexicon may have an error, or be missing a word;[14] or the grammar may have an error. Discovering such errors goes beyond the scope of this article; suffice to say that building parser debugging tools is another area needing attention.

Ultimately, such problems must be fixed, and when the error turns out to be in the grammar, it must be possible for the human to understand that grammar. One method that is often used in ordinary computer programming is to embed comments in the program code, which can be ignored by the computer. It is an oft-lamented fact that computer programmers frequently fail to comment their code, or comment it inadequately. As it happens, linguists have—if anything—the opposite problem: a traditional descriptive grammar is all comments, and no code! The grammar writing framework we are advocating here has both comments—the descriptive grammar—and code—the formal grammar. Moreover, because the formal grammar is scattered in the form of fragments throughout the descriptive grammar, each fragment is explained by the nearby text, and exemplified by the nearby ex-

[14] Frequently these are proper names or loan words.

amples. This obviously contributes to the human understandability of the formal grammar, and therefore to a human's ability to debug it. This is not to say that it the intent of each statement in the formal grammar is likely to be immediately obvious, but our mingling of the formal and descriptive elements of the grammar certainly makes the reader's learning curve for the notation less of an impediment.

6.4 **Self-documenting** Linguists have long used formal conventions for linguistic constructs. For example, in the past phonological rules were often written like either of the following:

(1) $\left\{ \begin{array}{c} b \\ d \\ g \end{array} \right\} \rightarrow \left\{ \begin{array}{c} p \\ t \\ k \end{array} \right\} / \_\_\#$

(2) $\left[\begin{array}{c} -sonorant \\ -continuant \end{array} \right] \rightarrow [-voiced] / \_\_\#$

The curly braces in (1) represent an ordered list of alternatives, implicitly matched between the two braced sets ('b' corresponds to 'p', 'd' to 't', and 'g' to 'k'), while the square braces in (2) represent an unordered set, both elements of which must be true (a phoneme to which this rule applies must be simultaneously non-sonorant and non-continuant). In both cases '#' is represents a word boundary. While the meaning is probably clear to most linguists today, the reliance on arbitrary characters is troubling from the perspective of long-term understandability. Will a reader a hundred years from now understand these notations, or notations for rules of epenthesis, deletion, reduplication etc.? And does the rule apply simultaneously, left-to-right iteratively, or right-to-left iteratively? Both notations are silent on this latter question.

In order to avoid this issue of ambiguous or non-readily understood notations, our formal grammars use explicit labels on all linguistic constructs, in the form of XML tags. An example is the following, encoding rule (1) above:[15]

(3)
```
<Ln:PhonologicalRule direction="simultaneous">
  <Ln:subrules>
    <Ln:PhonologicalSubrule>
      <!--- b -> p --->
    <Ln:input><Ln:refPhoneme idref="b"/></Ln:input>
       <Ln:output><Ln:refPhoneme idref="p"/></Ln:output>
    </Ln:PhonologicalSubrule>
    <Ln:PhonologicalSubrule>
      <!--- d -> t --->
      <Ln:input><Ln:refPhoneme idref="d"/></Ln:input>
      <Ln:output><Ln:refPhoneme idref="t"/></Ln:output>
```

[15] Each of the XML tag names in this example is preceded by a "namespace" prefix, here "Ln", distinguishing them from standard DocBook tags; this namespace also identifies the version of the XML schema to which the formal grammar tags belong. The implication is that if the schema is changed later, to correct some deficiency or add a new construct, the correct version of the schema will still be unambiguously identifiable. Also, a few comments in the example are enclosed in the XML comment format, using "<!-" before and "->" after.

```
      </Ln:PhonologicalSubrule>
      <Ln:PhonologicalSubrule>
        <!--- g -> k --->
        <Ln:input><Ln:refPhoneme idref="g"/></Ln:input>
        <Ln:output><Ln:refPhoneme idref="k"/></Ln:output>
      </Ln:PhonologicalSubrule>
    </Ln:subrules>
    <Ln:environments>
      <Ln:Environment wordFinal="true"/>
    </Ln:environments>
  </Ln:PhonologicalRule>
```

While this notation might seem cumbersome, it has the virtue of being unambiguous: the fact that 'b' corresponds to 'p', 'd' to 't', and 'g' to 'k', which was implicit in rule (1), is now made explicit.[16] Moreover, the use of an arbitrary character ('#') to represent the fact that the rule applies word-finally is now represented by an explicit attribute (`'wordFinal'`). And lastly, the function of each part of the rule is given by mnemonic XML tag names like '`Environment`', rather than by arbitrary characters (the slash on the left of rule (1), and the end of the line on the right).

At present, the formal grammar is written as raw XML using a programmer's editor, which provides support for open- and close-tag matching, syntax-directed coloring, schema validation, etc. We intend to build support for a structured editor for the formal grammar, analogous to the DocBook editor we are using for the descriptive grammar; we believe this would make the grammar writer's learning curve much easier.[17]

This XML notation can, in principle, be typeset in a simpler format, such as that of rule (1) above. Notice that the process of typesetting does not change the underlying XML representation, which remains unambiguous and self-documenting, and therefore suitable for long-term archiving. We have not yet written the program to convert the formal grammar from the XML into a typeset format like (1), but it would use mechanism similar to that used to produce the typeset DocBook XML.

6.5 **Linguistic theory behind the formalism** The reader may wonder why the formal grammar fragment in (3) uses phonemes, rather than phonological features. This may seem particularly odd in view of the earlier discussion of the need for broad typological and linguistic coverage. In fact, most of the machinery which the formalism makes available would be comprehensible, if not already familiar, to an American structuralist from the 1950s. This is a conscious decision, motivated by several factors.

[16] The individual phonemes to which the rule applies are encoded elsewhere,in the formal grammar, as a part of the phoneme inventory (or alternatively, a grapheme inventory) of the language. The input and output of the rule therefore refer to those phonemes defined elsewhere by means of an XML "`idref`". The idref can be any string; in practice, we usually use longer names than are shown in the example, like '`phG`' for the phoneme 'g'.

[17] For now, we use either jEdit or emacs, although there are other programmer's editors that would work as well. XML-specific editors such as Oxygen and XMLmind also exist; what we have not yet developed for those editors is a Cascading Style Sheet (CSS) that would enable on-screen formatting, in place of the raw XML tags.

First, linguistic theories are diverse, and change frequently. If we chose to model one of the latest theories, we would risk making it usable by only the current practitioners of that model—losing both present and future linguists who might prefer a different theory. Instead, we choose to model grammars using a theory which is long past its popularity, but which is stable and relatively easy to understand; paradoxically, we believe this allows its use by linguists of many different theoretical persuasions.

For example, the fact that we do not use phonological features renders arguments over feature underspecification irrelevant. This not only means that we do not need to take a stand on this issue, but that a linguist using our system for practical work does not need to worry about which theory of the application of phonological rules to underspecified representations we have used—our representations consist of phonemes, boundary markers and the like, all of which are either present or not.

Moreover, the use of a theory which is in large part fifty years dead means that most of the problems with it have been worked out. And as it turns out, most of those problems are either solvable by the addition of a few ideas from later eras (such as ordered phonological rules), or have no effect on observational adequacy. Before turning to the additions we have made to what would otherwise be a 1950s-era linguistic model, I will clarify why we are content with observational adequacy.

Chomsky (1964, 1965) introduced three levels of linguistic adequacy: observational, descriptive, and explanatory. A grammar which met the *observational level of adequacy* would be capable of generating all and only the sentences of the language—or, if one's interests were confined to morphology and phonology, all and only the possible word forms of the language.

A *descriptively adequate* grammar would go further, to account for intuitions that native speakers have. For example, a descriptively adequate grammar of English syntax might provide structural descriptions which would allow for disambiguating the two meanings of sentences like "The chicken is ready to eat." In phonology, it has been argued (Chomsky & Halle 1965) that the intuition by native speakers of English that the non-word *blick* would be a more acceptable English word than the non-word *bnick* is due to the internal phonological grammar that English speakers have, and that a descriptively adequate phonology of English should account for this.

Finally, a linguistic theory (as opposed to a grammar) is said to attain to the *explanatory level* of adequacy if it explains how a child acquires a descriptively adequate grammar. In Chomsky's view, a theory might provide multiple grammars, each with alternative representations of the surface strings to which a child is exposed. An explanatorily adequate theory would not only generate these multiple candidate grammars, but would also provide a mechanism for the child to choose among them.[18] One aspect of this search for explanatory adequacy has been the search for theories which rule out what are taken to be "impossible" grammars, i.e. grammars which correspond to no (attested) language.

Much of the theorizing that has gone on in linguistics over the last fifty years has been about these descriptive or explanatory levels of adequacy. For instance, the original argument in favor of feature-based representations of phonology, as opposed to phoneme-based representations, was based on the notion that an explanatorily adequate theory required a

[18] Providing a method for choosing among competing grammars accounting for corpus has in fact been done in machine learning of computational morphology (Goldsmith 2001).

feature-based representation in order to make the right predictions about which rules were natural and which were not (Chomsky & Halle 1965). But I claim that for purposes of writing linguistic grammars of natural languages, neither descriptive nor explanatory adequacy is important. In fact, attempting to restrict grammar writing tools to describe only "possible" languages can be counter-productive: should the theories turn out to be mistaken, a tool based on them will be incapable of describing some languages. For example, some theories have required that phonological rules make reference to natural classes, where natural classes are to be defined in terms of conjunctions of phonological features. But in fact many phonological processes in known languages cannot be defined in those terms (Mielke 2008).

Since the goal of writing grammars of languages is generally to attain to the level of observational adequacy, and because a grammar formalism which aimed at a descriptive or explanatory level of adequacy runs the danger of being tied to an incorrect theory, we believe there is a danger in trying to build too much theory into the grammar writing formalism. This, then, together with the fact that a formalism which was tied to some recent (and possibly more descriptively or explanatorily adequate) theory might find a limited audience among present day linguists, as well as a hard-to-understand description for future linguists, implies that it is probably best to aim for a relatively simple model making use of whatever constructs suffice for observational adequacy. This partly coincides with the emphasis in "Basic Linguistic Theory" (Dryer 2006, Dixon 2010) on the observational level of adequacy; but the approach described here differs in its emphasis on the need for a formal—and specifically computationally interpretable—system of grammatical description, as opposed to more or less purely verbal descriptions, which I have argued are far too ambiguous for grammar verification.

There are several aspects of our model in which the goal of observational adequacy has driven the incorporation of linguistic theorizing more recent than the structuralist era. The use of ordered phonological rules has already been mentioned. There is no distinction in the model between morphophonemic rules and allophonic rules, and all such rules may refer to exception features and grammatical information; similarly, the model makes no distinction among archiphonemes, phonemes, and phones. But there is provision for rule strata, and there is nothing which would prevent a grammar writer from confining morphophonemic rules to a deep stratum, and allophonic rules to a shallow stratum, or from distinguishing among archiphonemes, phonemes, and phones by means of the strata for which they are defined. (Most practical orthographies preclude the need to refer to allophones, of course.)

Another aspect in which the model incorporates more recent linguistic theorizing lies in the use of Item-and-Process descriptions, in addition to Item-and-Arrangement descriptions. The term Item-and-Process has in fact been used in two ways (Maxwell 1996): to describe the generation of allomorphs by phonological ("morphophonemic") processes, and to describe the generation of non-concatenative affixes, such as reduplicants. The grammar formalism allows for both of these; the use of phonological rules to modify affix forms has already been described, while the generation of non-concatenative affixes is provided for by a mechanism similar to that used in Munro & Benson (1973) and Carrier (1979).

At the same time, it must be admitted that the grammar formalism we have developed is, in some cases, incapable of attaining even observational adequacy. The clearest example of this is under-application of phonological rules to words containing reduplicants (Wilbur

1973). While there are a number of analyses of this phenomenon from various perspectives (Marantz 1982, McCarthy & Prince 1995, Raimy 2000, Inkelas & Zoll 2005, Frampton 2009), none of these analyses lend themselves to a straightforward formalism for grammar writing. I thus leave this problem for future enhancements of the grammar formalism.[19]

Our grammar formalism also has limited capabilities for syllabification, apart from the use of ordinary phonological rules to insert markers of prosodic structure. But that inserted structure is not on a different level (or plane): there is no notion in the current model of the distinction some theories make among a segmental tier, a timing tier, and a prosodic tier. Such structures could be added to the model as future enhancements, although for the reasons outlined above, it would be unwise to tie such enhancements too closely to particular theories of phonological structure.

6.6 **Compatibility with other linguistic formalisms** A final desideratum is compatibility with existing standards for language description. There are already useful standards for some sorts of linguistic objects, and the grammar formalism described here is intended to work together with those standards. Of particular interest are standards for lexicography, specifically the ISO standard for the Lexical Markup Framework (LMF, ISO/TC 37/SC 4, 2008; see also http://www.lexicalmarkupframework.org/).[20] The ISO standards for feature structures (ISO/TC 37/SC 4, 2006) and feature structure declarations (ISO/TC 37/SC 4, 2007) are also used in our formalism; this pair of ISO standards for features corresponds to the TEI standard (chapter 18 of http://www.tei-c.org/Guidelines/P5/).

7 Building a parser

> The second major design goal [of TeX] was to be *archival*... When the next generation of printing devices came along, I wanted to be able to retain the same quality already achieved, instead of having to solve all the problems anew. I wanted to design something that would still be usable in 100 years. (Knuth 1986:559).

The formal grammar is intended to be convertible into a morphological parser, so that the grammar's claims can be tested against real data—both example data in the grammar, and corpus data. A parser is built of three things: the grammar, a dictionary, and a parsing engine. The parsing engine constitutes the language-agnostic aspect of the parser, while the grammar and the dictionary constitute the language-specific aspects. Both the grammar and the dictionary must be in the format required by the parsing engine.

The dictionary can be either monolingual or bilingual; present day parsing engines normally use only the monolingual parts of a bilingual dictionary, in addition to any grammatical information. More specifically, the dictionary must provide the stem, plus whatever grammatical information the grammar expects, minimally the part of speech. For some languages, the parser will also need to know the paradigm class and/or stem allomorphy

[19] The over-application of phonological rules to reduplicants can often be handled by ordering the rules in question before the application of the reduplication process, as discussed in Carrier (1979) and Marantz (1982).

[20] There are other proposed standards for lexicons; the choice of compatibility with the ISO standard was driven by pragmatic reasons. The RELISH project (http://www.lat-mpi.eu/latnews/2010/08/relish-workshop-on-lexicon-standards-and-lexicon-tools/) is aimed at reconciling some of these different standards.

class of each lexeme. This information is often not directly represented in lexical entries, but must be inferred. For example, in languages where the paradigm class can be deduced from a single form, it may be possible to use a subset of the grammar's rules to isolate the stem from an inflected citation form and simultaneously infer the paradigm class. Where stem allomorphy classes exist, or where the paradigm class cannot be inferred from a single citation form, dictionaries often provide several citation forms and the user of the dictionary is expected to infer the relevant information from those forms. In this case, a specialized inference process will be needed to convert entries into the form needed by the parsing engine. For further details on the conversion of dictionaries into the form needed by the parsing engine, see the appendix.

Turning to parsing engines, at present morphological parsing is usually done using finite state transducers, such as the Xerox finite state transducer toolkit (`xfst` and `lexc`) described in Beesley & Karttunen (2003). Such transducers serve as both parsing engines and generating engines; that is, given a grammar and one or more lexicons written in the transducer's programming language, they perform a bidirectional mapping between surface forms and underlying forms. Finite state transducers are generally capable of modeling virtually all the morphological and phonological constructs in our formal grammar model, although some aspects are handled clumsily in my opinion, and grammar debugging can be difficult.

In all likelihood, whatever parsing engines are considered to be state of the art today will some day be replaced by other parsing engines, with added capabilities. This is of course the reason for describing the grammar formally in XML, as discussed above: we want to be able to easily port the formal grammar to a new parsing engine. Any piece of software, such as a parsing engine, becomes obsolete when it only runs on obsolete hardware. While such software can in principle be run on hardware emulators (Borghoff & Schmitz 2003:chapter 4), that is not a formula for making a parser widely usable. At any rate, much software today is not tied to hardware so directly; in fact, there are already parsing engines (such as the Stuttgart Finite State Transducer, SFST: (Schmid 2005)) that are open sourced, and can be compiled and run on most computers with the necessary programming language and libraries.[21] But even so, it seems unlikely that present day parsing engines will still be used a hundred years from now, and in our work we have already encountered problems with such open source software due to dependencies on older libraries, and even dependencies on particular hardware.

In a weaker sense, software also becomes obsolete when better software becomes available. One drawback to finite state technology for morphological parsing is the clumsiness with which (I claim) it handles morphosyntactic feature structures, exception features, and so forth. Undoubtedly there will be future parsing engines which handle this sort of thing more easily (or even more accurately), and it would be unfortunate if the grammar was unable to run on an improved parsing engine. Newer parsing engines are also likely to provide better grammar debugging facilities, which become important if a bug is found in the grammar, or if the grammar is to be ported to another dialect or to a related language.

[21] A "library" in computer parlance is a module of computer code which accomplishes some generally useful set of tasks, such as reading in a file, or manipulating strings of characters. Such libraries are occasionally updated, sometimes without retaining backwards compatibility.

We thus find it important to write our formal grammars in our XML format, abstracting away from the programming languages used by particular parsing engines, such as `xfst` and SFST. However, given the differences between the XML format for the formal grammar on the one hand, and these parsing engines' programming languages on the other, there is an obvious need for a conversion from the XML format into the programming language formats. We have written a converter for most (but not yet all) of the XML elements into the SFST programming language; the output of this converter (plus the required dictionary files in the SFST format) is then compiled by the SFST compiler to produce a parser. Further details of the working of this converter are provided in the appendix to this paper.

The converter has been used with the SFST parsing engine and suitable lexicons to produce parsers for Bangla, Urdu and Pashto (the latter in progress) and the parsers have been tested on examples extracted from the respective descriptive grammars and from corpora. As is usual with parsing, not every test word gets parsed correctly. Error analysis shows these to be due to the usual sorts of causes of parse failures: lexemes that are not in the dictionary, misspellings or alternative spellings, dialectal forms, and so forth. In other words, the converter is correctly converting the formal grammar into the form needed by the parsing engine, and the parsing engine is performing correctly, given the grammar and lexicon.[22] There have of course been errors in our formal grammar, although we believe these have been fixed now.

When the parser discovers a form which cannot be parsed due to an error in the formal grammar, we of course fix the formal grammar; but we usually also improve the descriptive grammar, since generally the mistakes in the formal grammar are due to misunderstandings of, or mistakes in, the descriptive grammar. An account of this process is given in David & Maxwell (2008). The result is that our descriptive grammars become more accurate than they would otherwise have been. Hence not only our formal grammars, but also our descriptive grammars, benefit from having a built-in validation mechanism. In summary, our grammar research is not only *archivable* and *reproducible*, but also *producible*: we have a method for ensuring the correctness of our grammars.

8 Conclusion Writing about reproducible research, Buckheit and Donoho (1995: 23) comment that

> Pasteur had the revolutionary idea to advance reproducibility in the biological sciences by adding sections to articles which gave Materials, Procedures, Methods of Analysis, and so on. The idea of carefully spelling out how a biological experiment was performed, and the nature of the biological specimens employed, seems so natural and automatic today, but at one time such information was not provided as part of scientific publication. After Pasteur, the accepted norms changed, and such information was furnished as a routine part of publication.

While perhaps a less momentous change for linguistics, it is nevertheless my hope that reproducibility will become the standard in our discipline, so that other researchers, both

[22] Other common causes of morphological parse failure include proper names, place names, numbers, and other sorts of tokens which are not accounted for by most grammars. We often tag such items in the examples and in our test corpus which we do not attempt to parse, so as to avoid trying to figure out why they don't parse.

those working today, and those studying our languages in the distant future, can verify and expand on our work. I believe that the best way to turn grammars into reproducible research is to embed a formal grammar into the descriptive grammar, in such a way that the grammar can be automatically converted into a parser with which the claims of the grammatical description can be tested against data from the descriptive grammar and from other corpora. The work described here constitutes such a system for morphology and phonology.

The formal grammar schema is currently being documented using the same Literate Programming methodology as that used for the grammars themselves. That is, the schema[23] has been broken into code fragments corresponding to the various linguistic objects, and each of these is described and illustrated with examples from natural languages. The completed documentation will be made freely available, along with the Python converter described above.

It remains to be seen if a similar system could be built for other aspects of grammatical description, particularly syntax. The difficulty in building an analogous formal grammar schema for syntax is that there is much less agreement among syntacticians as to what an observationally adequate grammar formalism might be. In large part, this is because syntax is more complex than morphology: syntax is usually thought to require at least a context free phrase structure grammar in the Chomsky hierarchy (Chomsky 1956), whereas morphology and phonology are generally considered to be finite state. Furthermore, it is much more difficult to construct grammatical analyses which approach observational adequacy in the sense of generating all and only the sentences of the language. Indeed, to my knowledge no one has ever written such a syntactic grammar, whereas comparable grammars (or better, parsers!) for inflectional morphology exist for many languages with non-trivial morphology. The gap between syntax and morphology may also be attributable to the fact that syntax is a younger linguistic domain than morphology and phonology. Nevertheless, it may be possible today to construct a syntax model which could cover a significant portion of the syntactic grammar of many languages, and which could be mapped into the programming language of existing syntactic parsers; indeed, Bender et al. (2010) describe an HPSG-based system which has been used to write syntactic grammars of a typologically wide variety of languages. In my opinion, combining such formal grammars with descriptive grammars along the lines described here would do much to bring syntax into the domain of reproducible research.

9 Appendix: Parser converter This appendix briefly describes the working of the program that converts our XML formal grammars into the programming language of the Stuttgart Finite State Transducer (SFST) parsing engine. The SFST code that results from this process is combined with the relevant lexical information, which we extract from electronic dictionaries of the target language. The SFST compiler is then run on the lexicon files and the converted grammar code, to produce a finite state transducer, which can be used both as a parser (converting surface forms into underlying forms) and as a generator.

Finite state transducers like SFST or the Xerox `xfst` are most efficient when the underlying form of the lexeme more or less resembles the surface form of the word. We have chosen to use the dictionary citation form of each lexeme as the representation of the underlying

[23] The schema is written in the Relax NG Compact syntax (http://relaxng.org/compact-20021121.html). This can be used by most schema validators, or automatically converted into the Relax NG XML syntax if desired.

form, even though this form may contain an inflectional suffix (such as an infinitival marker on a verb). The inclusion of such suffixes does little harm to the efficiency of the parser, and simplifies dictionary lookup (one of our applications being dictionary lookup given a non-citation inflected form); nor does the fact of occasional stem allomorphy significantly affect efficiency. It also gives us a clean separation between the phonology and morphology on the one hand, from semantics on the other, which would not be the case if we used glosses as the output of the parser.

Our converter works much like a modern programming language's compiler, in that it converts a high level language (the XML format) into a lower level language (the SFST format). The converter is written in the Python programming language, taking advantage of the object oriented programming features of Python: each element of the XML corresponds to a class defined in Python.[24] This part of the conversion is thus independent of the programming language of the targeted parsing engine, and corresponds to the front end of a traditional programming language compiler. The back end of our converter then translates this intermediate representation into the programming language of a particular parsing engine. In particular, the front- and back-ends of our converter correspond to the front- and back-ends of a multi-target programming language compiler. In the case of the programming language compiler, the multiple targets are the assembly languages of multiple CPUs; in the case of our formal grammar compiler, the multiple targets are the programming languages of different parsing engines. The motivation of this is that when it becomes desirable to port formal grammars to a new parsing engine, it will only be necessary to write a new back end for the converter; the front end remains the same.[25]

Each Python class in the converter, corresponding to an XML element, defines how it is to be converted into the parsing engine code. A class representing a phonological rule, for example, outputs the overall rule structure required by the parsing engine; the individual parts of the phonological rule are then recursively called from the converter at the appropriate points. For SFST for example, the equivalent of a phonological rule consists of the assignment to a variable of the rule itself. The converter for a phonological rule thus outputs the variable name, an equal sign, the input and output of the rule (represented as a set of correspondences), a symbol like '^->', the representation of the rule's environment, and a newline. (The arrow-like symbol thus represents not the input *becoming* the output, but rather an implication that when the input becomes the output, it will be in the context of the environment.) In a rule of deletion, the output is represented by a special symbol '<>'. Rules of epenthesis are slightly more complex, since SFST's notation does not directly sup-

[24] An anonymous reviewer asked why the compiler was written in Python, rather than in XSLT (Extensible Stylesheet Language Transformations). One reason is that the transformation from XML to SFST code is not linear; the XML phoneme definitions, for example, are used to define the SFST alphabets, and also to define the environments of phonological and allomorph rules, with large amounts of SFST code to be generated between those two uses. While it may not be impossible to program this sort of thing in XSLT, it is much simpler in Python. The author also confesses that he is much more familiar with Python than with XSLT.

[25] Typical multi-target compilers for programming languages often have in addition an optimization phase between the generation of the intermediate code and the generation of the target machine's code. While finite state transducers perform their own optimization for run-time, it turned out that some optimization of the code needed to be done for SFST, lest the SFST compilation phase use too much memory. This optimization is done during the SFST-specific code generation; it seems unlikely that exactly the same optimization will be necessary for other parsing engines.

port such rules, and it is necessary to compile them as deletion rules, then invert their input and output.

A simple example of the conversion from the XML format to the programming language of a parsing engine—here SFST—appears in the Python function in (4):

(4)
```
def SFSTOutput(self, sFormat, ExtraArg=None):
    """
    Output this context in the form expected by SFST, i.e.
    ( X | Y | Z )
    """

    if sFormat == 'AsRegex':
     self.SFSTOutputList("PhonologicalContexts",
                         "(",
                         "|",
                         ")",
                         sFormat)
    else:
      AbstractClasses.LangClass.SFSTOutput(sFormat, ExtraArg)
```

This `SFSTOutput()` function is defined for the class `AlternativeContexts`, which encodes a set of alternative phonological contexts forming part of the environment of such a phonological rule (or a phonologically determined allomorph); for example, the context of a long vowel *or* a vowel plus consonant. The function is called with an argument list specifying (among other things) a format. The only format this particular function knows about is called `AsRegex`; any other format is referred by the '`else`' clause to a superclass of `AlternativeContexts` (here `AbstractClasses.LangClass`). Given this `AsRegex` argument, the function needs to output the alternatives in the format which SFST expects for a regular expression, namely a parenthesized list with list members separated by the character '|'.

Since outputting of lists with various delimiters is a common task, the details of outputting the list (such as the need to output the separator character after every member of the list except the last) is here delegated to a more generic function, `SFSTOutputList()`, which takes as additional arguments (parameters) the character which starts the list (here an open parenthesis), the separator character ('|'), and the character which marks the end of the list (a close parenthesis). This `SFSTOutputList()` function is not shown here; it is defined on an abstract superclass of `AlternativesContext`. The XML elements which constitute the alternatives (represented by X, Y and Z in the quoted comment) will be recursively output by `SFSTOutput()` functions defined on whatever classes these individual contexts belong to.

For example, suppose a part of the grammar contains the following XML element (which happens to define a set of alternative contexts in Bangla[26]):

(5)
```
<Ln:AlternativesContext>
```

[26] This example is for expository purposes. From a theoretical perspective, it could be better treated as a context consisting of a single natural class, namely the vowels /i/, /u/ and /a:/.

```
    <Ln:SimpleContextTerminal>
      <Ln:refPhoneme idref="I"/>
    </Ln:SimpleContextTerminal>
    <Ln:SimpleContextTerminal>
      <Ln:refPhoneme idref="U"/>
    </Ln:SimpleContextTerminal>
    <Ln:SimpleContextTerminal>
      <Ln:refPhoneme idref="AA"/>
    </Ln:SimpleContextTerminal>
  </Ln:AlternativesContext>
```

When this snippet of XML is read by the converter, its elements will be converted into objects of the corresponding classes in the converter. The outermost element is an `AlternativeContexts`, and when the converter outputs this in the SFST format, the `SFSTOutput()` function in (4) will be called. It will then call the `SFSTOutputList()` function with the appropriate arguments; this function in turn calls the `SFSTOutput()` functions for the list members, namely for the simple contexts, which in turn output their information. For SFST, it happens that the simple contexts need only tell the phonemes[27] to output themselves in the SFST format, completing the process. The resulting SFST code would look like this:

(6) (i|u|aa)

assuming a romanization; the actual Bangla parser uses Bengali Unicode characters, as follows:[28]

(7) (ি | ু | া)

If the converter needed to produce code for a different parsing engine, very little of the above code would need to change. In the case of the Xerox transducer (`xfst`), the only change would be to replace the parentheses with square brackets.

The code generator in (4) is simple, but some parts of the SFST code generator are comparatively complex, particularly the parts needed to handle morphosyntactic feature checking. The reason for the complexity is the fact that finite state transducers tend to treat the symbols for such features and their values as funny kinds of phonological characters, which have to be ignored in some circumstances, but paid attention to in others. It seems likely that future parsing engines will have special machinery for such features, which will considerably reduce the complexity of the converter. Even at present, though, the special machinery in the converter is hidden from the user, who need only worry about the higher level linguistic formalism.

[27] The phonemes are defined once in the formal grammar, and thereafter referred to; hence the `idrefs` in the XML snippet, which simply point to the definitions of the individual phonemes.

[28] Again, the actual situation is more complicated: the Bengali script has both vowel "signs" (shown in the example) and individual vowel letters (not shown). The parser must in general handle both. The dotted circles in (7) represent the position of the consonant symbol relative to the vowel symbol, and are a purely visual effect of using a Unicode-compliant font to display the vowel signs in the absence of such a consonant.

While defining a formal grammar, and choosing a target parsing engine, allows us to straightforwardly define the converter code for the grammar in a language-independent way, dictionaries are a different matter. The target for dictionary converter code is defined by the parsing engine, but unless a dictionary is already in a standard format, converting the dictionary entry into that form must be done differently for each dictionary. Even when the dictionary uses a standard format (such as the ISO Lexical Markup Framework, ISO/TC 37/SC 4 2008), dictionaries of different languages may represent such things as inflection classes or stem allomorphy classes differently. As mentioned in the text, in some cases such classes may be represented only implicitly, by listing certain irregular forms; the morphosyntactic properties of these irregular forms must then be inferred. It may also be necessary to remove affixes from citation forms or irregular forms to obtain the stem. Fortunately, the structure of dictionaries–at least the parts that are needed for morphological parsers–is not as complex as grammars. In particular, senses and glosses, example sentences, and phrasal entries or phrasal sub-entries, can all be ignored.

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Advances in the accountability of grammatical analysis and description by using regular expressions

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This paper discusses the representativeness, coextensitivity and scientific accountability of corpus-based grammatical descriptions of previously unresearched languages. While a grammatical description of a previously unresearched language can hardly be representative for any kind of its varieties, it can be adequate in coextensitivity if it covers the linguistic phenomena presented in the corpus. In order to allow other researchers to retrieve the examples in their context and check the analysis, the corpus should not only contain text collections, but also the elicited data, provide metadata and be accessible to other researchers. Scientific accountability, however, can only be achieved, if the description facilitates the replicability of the analysis, which presupposes that the authors' corpus linguistic search methods are documented, so that the readers can find other, if not all examples for the described phenomena, and scrutinize the search methods, the analysis and the description. As is illustrated in this paper, a suitable query language for this kind of scientific grammatical analysis and description are the so-called regular expressions which are implemented in the annotation tool ELAN.

Drawing on my experiences as a grammaticographer for the past thirty years, I want to discuss the question to what extent digital grammaticography contributes to the accountability of grammatical descriptions by comparing my earlier traditional methods of grammatical analysis with those that I have recently started practicing in the Teop language documentation project.[1] Teop is an Austronesian Oceanic language spoken in the Autonomous Region of Bougainville, Papua New Guinea, and genetically related to the other two languages, Tolai and Samoan, for which I wrote grammatical descriptions (Mosel 1984, Mosel & Hovdhaugen 1992).

On the basis of a language documentation corpus of approximately 260 000 words, which is slowly, but constantly growing, I am currently writing a non-electronic Teop reference grammar that hopefully could one day be transferred to an electronic format and be linked to our Toolbox lexical database (Schwartz et al. 2007) and the ELAN text corpus (Mosel et al. 2007). The grammar starts with an introductory phonology chapter and an overview of

[1] The Teop Language Documentation project was funded by the DoBeS programme of the Volkswagen Foundation from 2000 to 2007. Subsequently the project "A corpus-based grammar of Teop, an Oceanic language of Bougainville, Papua New Guinea" was funded by the Deutsche Forschungsgemeinschaft from 2008-2011.

	Conventional corpus	**LD corpus**
language	well-researched standardized European language	unresearched, non-standardized non-European
texts	available in print and on-line	recorded, transcribed, translated
corpus builder	team of professional native speakers	single non-native speaker in cooperation with non-professional native speakers
size	millions of words	below 1 million
purpose	linguistic research	language preservation linguistic and anthropological research

TABLE 1.: Conventional vs. language documentation corpora

the structure of phrases, clauses and complex sentences, and then proceeds in the traditional ascending linear fashion from word classes and morphology to simple clauses and complex sentences (Mosel 2006a). Each chapter is selfcontained and can be read by itself once the reader has read the introductory overview. The language documentation (LD) on which the grammar is based is archived in the DoBeS archive.[2]

1 LANGUAGE DOCUMENTATION AND CORPUS LINGUISTICS Writing a grammar on the basis of a language documentation is a corpus linguistic enterprise, but as LD corpora are quite different from the large corpora of European languages (see Table 1 for a summary), LD grammaticography has to develop its own corpus linguistic approach aiming at grammatical descriptions that are reasonably complete from a typologist's point of view, but would also be representative for the linguistic data contained in the corpus. This latter kind of coverage is called coextensivity by Good (this vol. §1.5.1).

2 THE NOTIONS OF COMPLETENESS, COEXTENSIVITY AND SAMPLE REPRESENTATIVENESS To what extent a LD grammar is a comprehensive grammar depends on the "documentary coverage", i.e. "the extent to which a documentary corpus actually includes the information needed to create a complete grammar of the language." (Good this vol. §1.5.1) In contrast to this generally defined notion of completeness, the notion of coextensivity relates the content of a grammar to the particular linguistic data that are available in the corresponding LD corpus. A grammar that is based on a small corpus may not be "complete" in a typological sense, but its coextensivity would be adequate, if it covers all the information that an analysis of the corpus can provide.

Linguists working on LD grammars agree that a grammar should be data-driven and accompanied by a corpus in order to facilitate the verification or falsification of the analysis (see Nordhoff (2008) for a summary of what is considered a good grammar by typologists, and Bender et al. (this volume)). But what is less clear is how the degree of coextensivity of a grammatical description can be made evident by the grammaticographer and consequently be skrutinized by the reader.

[2] http://corpus1.mpi.nl/ds/imdi_browser/?openpath=MPI77915%23

Good (this vol. §1.5.3) assumes that "it will often simply be not possible" to base a grammatical description "(more or less) on all of the available data. ... Instead, it should be based on a sample of the data that results in a description that is representative of all the collected data." But how we can know to what extent this sample would be representative without analyzing more data remains unclear. Good himself admits "In any event, the question of what kind of sample of documentary materials can be considered representative enough to form the basis of a description that would also cover the remaining materials appears to be an interesing one, and work in this area would be quite useful for developing general methods for assessing adequacy in coextensivity."

Since representativeness can hardly be achieved in the small opportunistic corpora of LDs and the assessment of representativeness is still a matter of debate (Clancy (2010:86-87), McEnery & Hardie (2012:10)), I would restrict the notion of coextensivity to the relationship between the description and the selected text collection on which the description is based and strictly distinguish it from the notion of representativeness which in corpus linguistics refers to the relationship between corpora and language varieties. Thus the description of a grammatical phenomenon is adequate in coextensivity, if it accounts for all its occurrences in the selected text collection, irrespective of the size and the kind of the collected texts. But this text collection may not be a representative sample for a particular register or genre. Conversely, a text collection may be considered representative for a register or genre, if it covers all or most of its grammatical phenomena, even if its grammatical description misses some grammatical phenomena and consequently lacks a high degree of adequacy in coextensivity. The writer of a LD grammar should aim at adequacy in coextensivity, which is solely his responsibility, whereas the representativeness of the text collection is beyond his control because it depends on the kind, size and number of texts the speech community supplies (Mosel 2006b).

3 Corpus building in a LD project As mentioned above, LD corpora are opportunistic corpora, i.e. corpora that "represent nothing more or less than the data that it was possible to gather for a specific task." (McEnery & Hardie 2012:11) In other words, the building of LD corpora does not follow previously specified corpus design criteria and hence would not qualify as corpora but merely as "electronic text libraries" for some corpus linguists (Atkins & Ostler 1992:1). But this does not mean that the texts of a LD could not be classified with respect to genres, themes, and situation characteristics, and accordingly organized into subcorpora. At least for frequently occurring grammatical phenomena the division of the corpus into such subcorpora may reveal regular patterns of contrasting constructions that are significant for distinct registers. While, for instance, in Teop narratives a sequence of actions such as the making of a fishing net or the butchering of a chicken is expressed by simple paratactic or coordinated clauses, the very same kind of sequences of actions is expressed by complex sentences with adverbial clauses in comparable procedural texts Mosel (forthcoming).

For the grammatical analysis and description of the Teop LD corpus, which now (May 2012) comprises approximately 260 000 words, we classified the texts according to their mode of production and genre into 11 subcorpora:

1. recordings and transcriptions of oral legends

2. edited versions of the transcriptions of the oral legends
3. written legends
4. recordings and transcriptions of personal narratives
5. edited versions of the transcriptions of personal narratives
6. written personal narratives
7. recordings and transcriptions of encyclopedic descriptions of things and activities
8. edited versions of the transcriptions of encyclopedic descriptions of things and activities
9. written encyclopedic descriptions of things and activities
10. interviews on cultural practices that have not been edited yet
11. example sentences that were provided by two native speakers for the Teop Lexical Database

A finer subclassification did not seem suitable because the more diversified the subclassification of a rather small text collection is, the more difficult it becomes to recognize regular patterns of language use.

The corpus is compiled in Elan, which facilitates simultaneous searches with the query language of Regular Expressions on several tiers such as the transcription and the free translation tier. Although parts-of-speech tagging and morphological glossing would make the grammatical analysis easier, we decided to gloss only a few texts because we wanted to record, transcribe and translate as many texts as possible. Consequently we only created three tiers for most texts:

1. the reference tier which gives each annotation a label that identifies the text and the number of the annotation, e.g. Aro_05R.003 for the third annotation of the fifth recorded spoken text of Arovina Magum;
2. the transcription tier;
3. the free translation tier.

Since Teop is nearly an isolating language and the corpus is accompanied by a lexical database in Toolbox and a sketch grammar (Mosel 2007), it is possible to understand the grammatical constructions and do the glossing in the future even if no native speakers are available. In the grammar the labels on the reference tier are used to indicate the source of all cited examples and thus allow to quickly retrieve them in their original context although the grammar is not linked to the corpus.

4 Accountability of grammatical descriptions Quoting Nordhoff (2008), Rice (2006:395), Noonan (2006:355), Weber (2006:450), Bender et al. (this volume:§8.4.1) postulate three maxims of best practices for the accountability of grammatical descriptions:

1. "If we value the application of the scientific method, more sources for a phenomenon are better than fewer sources."

2. "If we value the application of the scientific method, every step of the linguistic analysis should be traceable to a preceding step, until the original utterance of the speaker is reached."
3. "If we value the application of the scientific method, the context of the utterance should be retrievable."

Although many linguists agree on these maxims and the retrievability of examples in grammatical descriptions has a centuries long tradition in Classical Greek and Latin linguistics, most typological grammar writers do not bother to explicitely state the sources of their examples and thus bring discredit upon linguistic typology as a science of language. Having been educated in the old fashioned philological tradition, I tried wherever possible to quote examples from published original materials in my grammatical descriptions of Tolai and Samoan (Mosel 1984, Mosel & Hovdhaugen 1992) so that in principle most examples are retrievable. But as these publications are only available in a few public libraries, most readers don't have the chance to scrutinize my data and analyses. An exception is Gillian Sankoff (1993) who on the basis of my text collection (Mosel 1977) discovered that I overlooked the similarity between the Tolai focus particle *iat* and its Tok Pisin equivalent *yet* in my comparative study of Tolai and Tok Pisin (Mosel 1980). Due to the rise of documentary linguistics, however, it will soon become a standard that grammars are accompanied by digital corpora, provide easy access to the sources of the examples and thus fulfill the first and the third maxim quoted above.

The second maxim that each step of the linguistic analysis should be traceable is impossible to follow in traditional grammaticography. When analysing Tolai and Samoan texts, I wrote thousands of quotes on cards and stored them in shoe boxes. So I had boxes for alphabetically sorted functional words, for grammatical constructions, and interesting phenomena such as noun/verb distinction or idiomatic phrases for the expression of time, but when I recently realised that they won't be of any use for me or other linguists in the future, these boxes went into the recycling bin.

Electronic grammars which facilitate the retrieval of the examples from a corpus by one or a few mouse clicks reach a higher degree of accountability for practical reasons, but with respect to the second maxim they are in principle not much different from traditional grammars, if it is only the easy retrievability of examples that makes the difference. If one takes the request for scientific accountability and coextensivity seriously, one could go a step further and inform the readers of how the particular example was found and how other, if not all examples of the grammatical phenomenon in question can be retrieved from the corpus. This is at least to some extent practicable if one uses Regular Expressions for one's searches and documents their particular formulas.

As illustrated by the examples given below and in the appendix, regular expressions facilitate:

1. searching for discontinuous sequences of words;
2. searching for two or more alternative expressions at the same time;
3. searching for some expression with the exclusion of other expressions;
4. searching for reduplications.

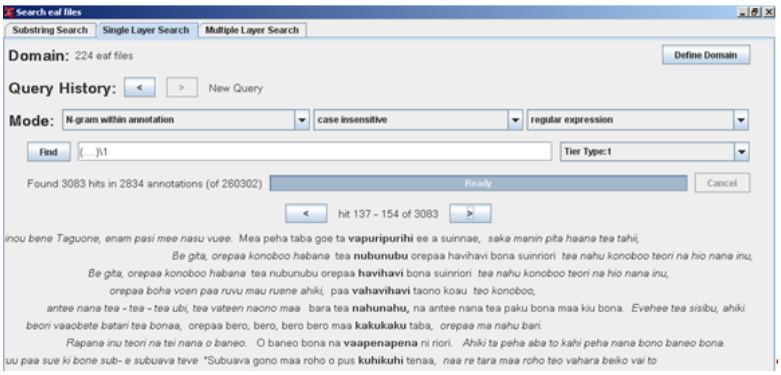

FIGURE 1.: Search for reduplicated wordforms

Using Regular Expressions for searches in an ELAN corpus also allows us to simultaneously search on several tiers and explicitly state

1. how many examples the corpus or a selected subcorpus provides for a particular construction;
2. if certain strings of words in the example represent frequent collocations or colligations;
3. how a grammatical formative or construction in question relates to alternative expressions in terms of frequency and/or register.

In sum, the use of regular expressions for searches and the documentation of these seraches in the grammatical description advances the degree of accountability of a grammar and allows more explicit statements about its coextensivity.

5 THE USE OF REGULAR EXPRESSIONS IN GRAMMATICAL ANALYSIS AND DESCRIPTION Most searches can be performed with quite simple formulas (see the appendix). For example, it is very easy to find all reduplicated word forms with regular expressions, which is impossible with simple word searches. Once I had observed that in Teop the reduplicated sequence is a prefix consisting of two, three or four letters, I could search for all reduplicated word forms, as illustrated here for reduplicants of four letters. The regular expression

(1) (....)\1

finds all sets of four letters that are repeated once, altogether 3083 tokens in the Teop Language Corpus, e.g. simple forms like *nubunubu, havihavi* and prefixed forms like *vapuripurihi, vahavihavi* and *vaapenapena*.

Using more complex formulas you can restrict the search to forms with or without affixes in general or to forms with particular affixes as briefly illustrated in the appendix. But here I want to present one of my most complicated examples, namely the investigation of the noun-verb distinction in Teop, and discuss its problems.

Oceanic languages are well known for their presumably weak noun/verb distinction (Hengeveld et al. 2004, Hengeveld & Rijkoff 2005), but the investigation of lexical flex-

ibility in Teop seems the first corpus-linguistic study of this phenomenon. The workflow of this investigation was as follows:

1. Identify the elements constituting the constructional frames[3] of noun phrases (NPs) and verb complexes (VCs) - a constructional frame consists of functional morphs and empty, syntactically defined head and modifier positions for content words and stems).
2. Identify the functional elements that directly precede or follow the empty head position for the content word.
3. Construct Regular Expressions for the head position in NPs and VCs.
4. Select a few prototypical frequent action and object words e.g. 'do, make', 'say', 'person', 'thing', and search.

In Teop the constructional frames of NPs and VCs are quite complex. But for our purposes it was sufficient to construct the formulas that only include those functional elements that immediately precede either the head of NPs or the head of VCs, i.e. the articles, a plural marker, the numerals for 'one' and 'two', and the diminutive particle for NPs and for the VC the pre-head tense, aspect and mood markers, the conjunction *re* 'so that, then', and the relative pronoun *to*:

(2) Regular expression for Teop NPs:
`\b(a|o|bona|bono|peha|peho|bua|buo|amaa|maa|si)\b`
`\bHEAD\b`

This formula means:

(3) find any lexical form that is inserted in the HEAD position and preceded by

- the specific basic article *a* or *o* or
- the object article *bona* or *bono*, or
- the numeral *peha, peho* 'one' or *bua, buo* 'two', or
- the plural particle *maa* or the complex form *amaa* consisting of the article *a* and the plural marker *maa*, or
- the diminutive particle *si*.

(4) Regular expression for Teop VCs
`\b(are|kahi|na|ore|paa|pasi|re|repaa|tau|to|toro)\b \bHEAD\b`

This formula means:

(5) find any lexical form that is inserted in the HEAD position and preceded by

- one of the six TAM markers *kahi, na, paa, pasi, tau* or *toro* or

[3] Compare the notions of collocational frame works, grammar patterns and colligates in Stefanowitsch & Gries (2009:936-937).

- the conjunction *re* 'then, so that' or
- the relative pronoun *to*, or
- the conjunction *re* with the 1inc.pl prefix *a-* , i.e. *are,* or
- the conjunction *re* with the with 3sg/pl-prefix *o-*, i.e. *ore,*
- or the conjunction *re* 'then, so that' with the suffixed TAM marker *paa,* i.e. *repaa*.

These formulas do not cover the full range of possible contexts of NP and VC heads. The most notable exception is the very first position of the clause. In fast speech the speakers sometimes omit the article of NPs or the tense/aspect particle of a VC. Furthermore, imperatives are always unmarked for tense, aspect and mood and are not preceded by the conjunction *re* or the relative pronoun *to*. Consequently, the search with these formulas cannot reach the highest degree of coextensivity, but at least the readers are informed about the method and the limitations of the investigation, which contributes to the accountability of the grammatical description.

A further problem is that some functional words are homonyms: the form *na* represents a TAM marker and a portmanteau morph representing the 3pers.sg. possessive marker and the article of the following NP, and *to* the relative pronoun preceding the VC and a rare non-specific article. This means that I either had to exclude these homonyms from my investigation or check all examples containing *to* and *na*. I opted for the latter, which was not too time consuming as the selected object words only rarely occurred with *na* or *to*. Had I chosen the first solution, the investigation would have been less coextensive, but would have still sufficed the accountability maxim as long as I documented my choice.

The result of these searches was, as shown in the table below, that action words and object words are flexible with respect to the head positions in NPs and VCs, but that, as expected, action words are much more frequent in the VC head position and object words are much more frequent in the NP head position. Further research which employed the same kind of strategy revealed that action and object words are morpho-syntactically distinct in modifier positions so that verbs and nouns are formally distinct word classes in Teop, but at the same time show flexibility with respect to the NP and VC head positions, which contradicts Hengeveld, Rijkoff and Siewierska's (2004) theory of lexical flexibility.

Since I only investigated a few prototypical action and object words, my grammatical description is strictly speaking not adequate in coextensivity. This would only be the case if I had analysed and described all action and object words of the corpus, which would have been too time consuming and also unnecessary in my prototype approach. As I document the Regular Expressions of my searches, the readers can re-enact them and test the formulas with other head words.

With lexical items the problem of homonymy can easily be solved by simultaneous searches on the transcription and the translation tier. In order to distinguish, for instance, the adjective *beera* 'big, elder, important' from the noun *beera* 'chief' or the adjective *beera* 'chiefly', you only need to search for *beera* on the transcription tier and its three translation equivalents on the translation tier.

If in the chapter on word classification I only gave the references for my examples, my description would be much less adequate in coextensivity, even if all of them were retriev-

		VC head	NP head			VC head	NP head
asun	'hit, kill'	70	1	*aba*	'person'	6	243
hua	'paddle'	115	4	*beiko*	'child'	1	366
mosi	'cut'	85	9	*iana*	'fish'	-	176
nao	'go'	1002	5	*moon*	'woman'	4	665
paku	'do, make'	996	10	*naono*	'tree'	-	136
pita	'walk'	63	3	*otei*	'man'	-	478
rosin	'flee'	211		*taba*	'thing'	11	461
sue	'say'	752	10	*vasu*	'stone'	-	48

TABLE 2.: The distribution of typical verbs and nouns as heads of VCs and NPs

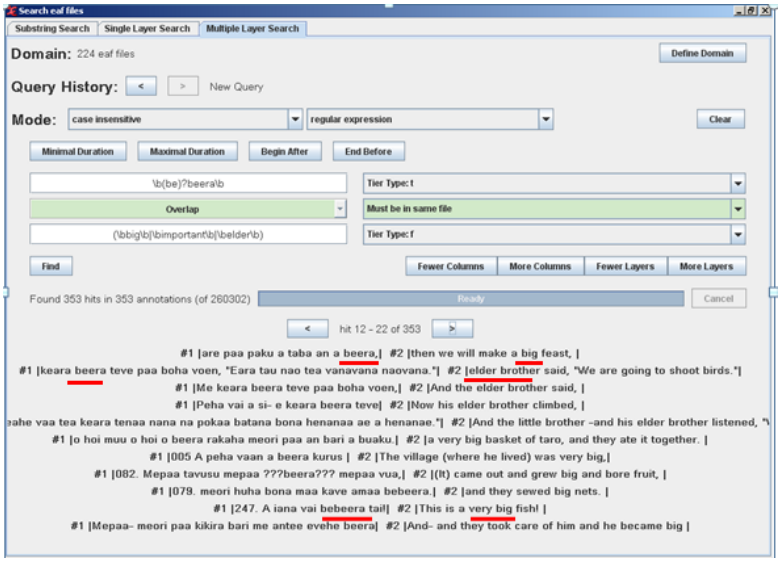

FIGURE 2.: Search for *beera* or *bebeera* with the meaning 'big', 'important' or 'elder'

able in the corpus because these few examples merely illustrate lexical flexibility, but do not demonstrate how my analysis and description actually relates to the corpus. Furthermore, the accountability of my description would be less scientific in view of the second maxim quoted above.

In the Teop Reference Grammar (Mosel in prep.) relatively simple and frequently used regular expressions as the one in Figure **??** are described in an appendix, whereas the application of complex searches is documented in the endnotes of each chapter. In an electronic grammar each example could perhaps be linked to its particular Regular Expression formula which together with all other formulas would be stored in a single separate file.

6 Concluding remarks Comparing my previous personal research methods with those of my current analysis of the Teop language, I am convinced that Whalen (2004) was right when he assumed that "the study of endangered languages will revolutionize linguistics." It is not only the way how we record speech by audio and video recordings, process the data in annotated digital corpora, make them globally accessible via the internet, and search them by the means of sophisticated query languages like Regular Expressions, but it is also the way how we - literally speaking - look at the data. Browsing through concordances as the ones depicted in Fig. 10.1 and Fig. 10.2 sharpens your eyes for regular patterns of language use and variation. It inspires you to create and test new formulas in your query language to either narrow down or extend your searches and thus explore the complex network of form-meaning correspondences in a hitherto unresearched language. With some practice you eventually "think regular expressions", as Friedl (2006:6) puts it, and understand how selected lexical units interact with certain constructions and, conversely, under which conditions selected constructions accommodate certain types of lexical units.

Unfortunately digital formats change so rapidly that digital archives cannot give long-term guarantees that they would continuously covert electronic grammars to new formats. Therefore I strongly recommend that the developers of electronic grammars provide for a function that facilitates the production of print outs and that these print-outs are stored in traditional libraries.

7 APPENDIX: SOME USEFUL REGULAR EXPRESSIONS FOR ELAN USERS This section only presents a very short introduction into what kind of searches can be done with regular expressions when analysing complex words or syntactic constructions. The best way to get started is just to try out what can be done with these formulas in your ELAN corpus or any other corpus that has implemented regular expressions. Note, however, that there are several dialects of this query language. For a comprehensive general introduction I recommend (Friedl 2006). There is not yet any specialised investigation on the use of regular expressions in grammaticography.

7.1 SYMBOLS The following list only comprises a selection of those symbols that I found most useful. I tested them with Teop and German.

symbol	place	meaning
`\b`	at the beginning and/or the end of a string	word boundary
`\w+`	at the end of a string	variable end of word
`.`	anywhere	any letter
`.*`	between spaces	any string of letters between spaces/any word
`.*\`	between spaces	any string of words
`(x|y)`	anywhere	either x or y
`[^x]`	place at the beginning	not x
`(....)\1`	anywhere	words with four reduplicated letters
`?`	after a letter	preceding letter is optional
`(xyz)?`	anywhere	the string xyz is optional

TABLE 3.: Symbols

7.2 Searching for particular complex word forms The symbols given in Section 7.1 can be combined for the search of morphologically complex words, especially for searches of words with particular suffixes or words containing reduplications. But the regular expressions do not recognise morpheme boundaries within a word.

symbols	hits	examples
`sa`	all words containing the string *sa*	*sa, vasaku, sahata, tisa*
`\bsa`	all words starting with *sa*	*sa, sahata, sana,* NOT *vasaku, tisa*
`\bsa\b`	all words *sa*	*sa*
`\bsa..\b`	all words consisting of *sa* and two letters that follow *sa*	*saka, saku, sana,*
`\bsa\w+`	all words beginning with *sa,* but not *sa* by itself	*sahata, sana*
`\b.*ana\b`	all words ending in *ana*	*sinana, tamuana, sana, bana, maana*
`\b[^(bana|maana)].*ana\b`	all words ending in *ana*, but not *bana* or *maana*	*sinana, tamuana, sana*
`(....)\1`	all words with four reduplicated letters	*pakupaku, vapakupaku, mahumahun, vamahumahun*
`\b(....)\1`	all words beginning with four reduplicated letters	*pakupaku* NOT: *vapakupaku*
`\b(....)\1ana\b`	all words beginning with four reduplicated letters and ending in *ana*	*vasuvasuana, hunuhunuana*
`\bva(....)\1`	all words with the prefix *va-* and four reduplicated letters	*vapakupaku, vagunagunaha*
`\bvahaa?\b`	all tokens of *vahaa* and *vaha*	*vahaa* and *vaha*

Table 4.: Searching for particular complex word forms: Combinations of symbols on word level

symbols	hits	examples
`\bsaka\b .* \bhaa`	string of 3 words: (1) *saka* (2) any word, and (3) the word *haa* by itself or with suffixes	*saka antee haa;* *saka abana haari;* *saka kabuu haana*
`saka .* \bhaa\w+`	string of 3 words: (1) *saka* (2) any word, and (3) a words beginning with *haa*, but not *haa* by itself	*saka abana haari*; *saka kabuu haana*
`\b(saka|sa)\b \bpaku\b`	all 2 word strings that consist of *saka* or *sa* and *paku*	*saka paku, sa paku*
`\b(saka|sa)\b .* \bvaha\b`	all 3 word strings with (1) *saka* or *sa*, (2) any word (3) *vaha*	*saka tii vaha* *sa tapaku vaha*
`\b(saka|sa)\b (....)\1 \bhaa`	all 3 word strings with (1) *saka* or *sa*, (2) a word with four reduplicated letters (3) the word *haa* or a word beginning with *haa*	*sa natanata haa*, *saka natanata haana*

TABLE 5.: Searching for particular sequences of words: Combinations of the symbols \b, `.*`, `\w+` and `(x|y)`

7.3 SEARCHING FOR PARTICULAR SEQUENCES OF WORDS Comments on Table 5:

saka/sa ... haa is a discontinuous negation. The last component *haa* can have a suffix that indicates imperfective aspect and person, e.g. *haana, haari, haara.* The formulas above provide data for the following questions:

1. Which words are used inbetween *saka* and *haa/haana/haari/haara*?
2. Which words are used inbetween *saka* and *haana/haari/haara* ?
3. Are there examples for *saka/sa* followed by *paku* 'do'?
4. Which words are used between *saka/sa* and *vaha* 'back, also, again, anymore'?
5. Does *saka/sa ... haa* combine with reduplicated words?

7.4 MULTILAYER SEARCH WITH REGULAR EXPRESSIONS Multilayer search is useful if you want to find examples of a homonymous lexical item or functional word as, for instance,

the Teop non-specific article *ta* 'any, some' which is homonymous with the noun *ta* 'part' and the complementizer *ta.*When I came across a sentence in which this non-specific article was followed by the demonstrative pronoun *vai* 'this' and a relative clause introduced by *to*, I searched for all examples of this extraordinary construction

(6) *ta .... X vai to*
ART .... X DEM REL
'any/some ... X that'

in the corpus using the formula `\bta\b .*\ \bvai\b \bto\b` on the transcription tier and `(any|some)` on the translation tier:

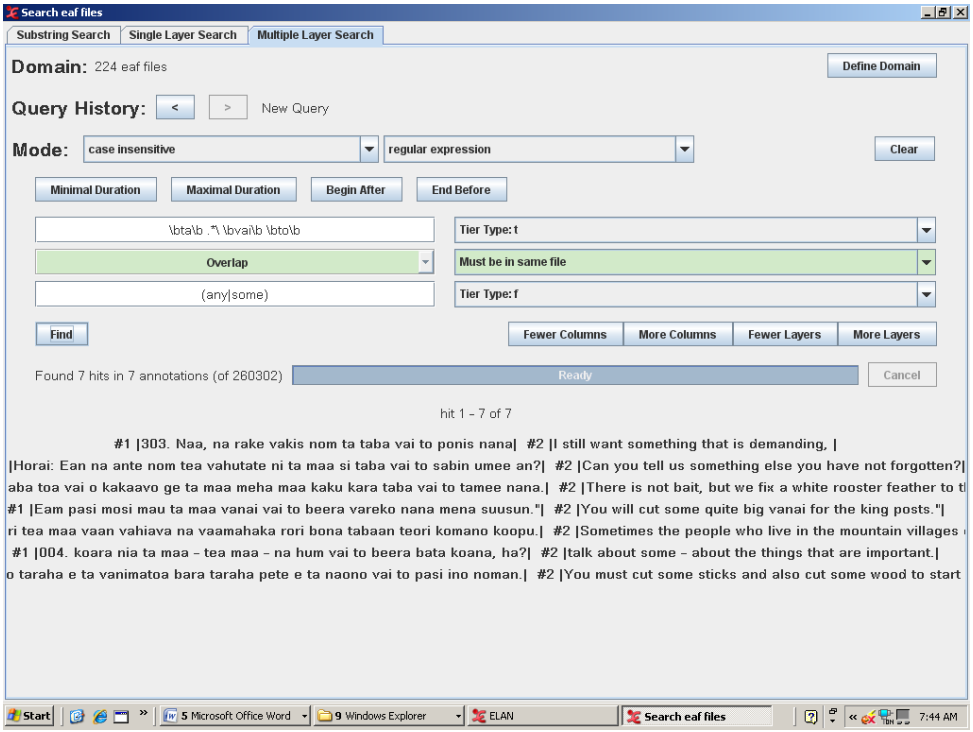

FIGURE 3.: Multilayer search for *ta* with the translation 'any' or 'some'

This formula means: search within an annotation for all occurences of *ta* meaning 'any' or 'some' that is first followed by one or more unspecified words and then by the demonstrative *vai* and the relative pronoun *to*.

Multilayer search is also practical, if you do not know the language well and want to search for a word and all its translations. Then you search on the free translation tier with the wild card .* For example, the search for *mararae* gives you the translations 'happy', 'joyful' and 'joy'.

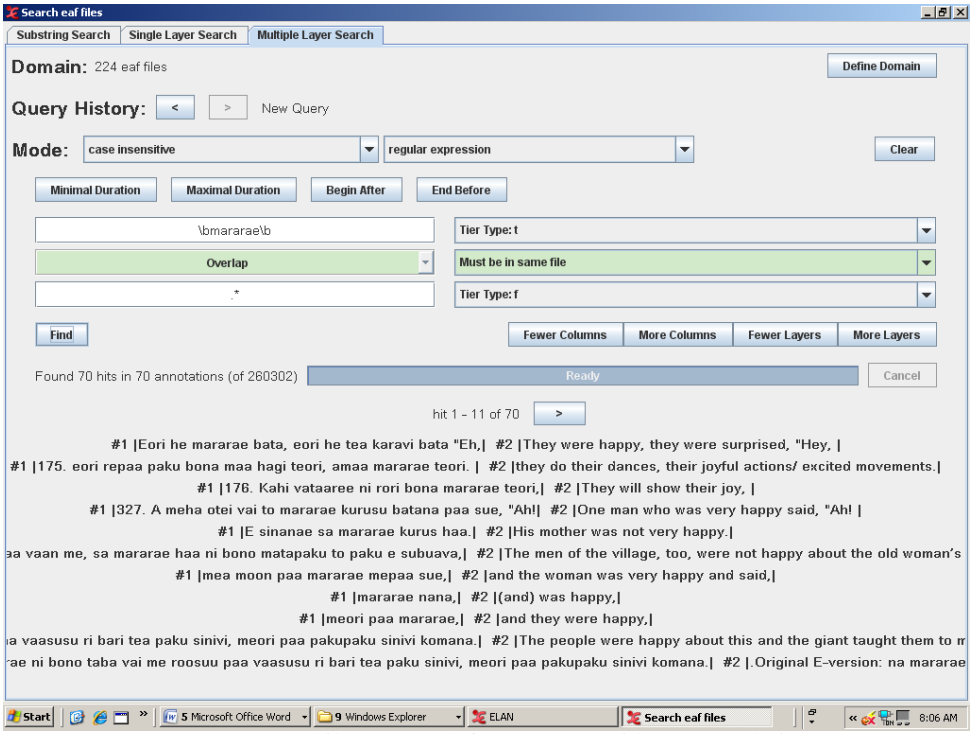

FIGURE 4.: Multilayer search for *mararae* with any translation

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Appendix

NORDHOFF'S MAXIMS The following is a list of Nordhoff's (2008) maxims:

1. Data quality.

1.1. Accountability. We value application of the scientific method.

(1) Every step of the linguistic analysis should be traceable to a preceding step, until the original utterance of a speaker is reached.

(2) Every phenomenon described should be sourced using an actual utterance.

(3) More sources for a phenomenon are better than fewer sources.

(4) The context of the utterance should be retrievable.

1.2. Actuality. We value scientific progress.

(5) A GD should incorporate provisions to incorporate scientific progress.

(6) The GD should present state-of-the-art analyses.

1.3. History. We value the recognition of the historic evolution of ideas.

(7) The GD should present both historical and contemporary analyses

2. Creation

2.1. Layout assistance and templates. We value speed of creation and comparability.

(8) Layout should be automatic as far as possible.

(9) A GAP which provides templates is better (Weber 2006a:430, 434).

2.2. Creativity.We value the individual mind's expressive abilities.

(10) A GAP that does not interfere with the creativity of the author is better

2.3. Collaboration.

(11) A GAP that does not require the writers to be present at the same place is better

(12) A GAP should show which collaborator has contributed what.

(13) A GAP which can be used both online and offline is better

2.4. Backup. We value safety of the data.

(14) A GAP should provide the author with regular automated backups

3. Exploration.

3.1. Ease of finding. We value ease and speed of retrieving the information needed.

(15) A GD which has a table of contents, an index, and full text search is preferable

(16) A GD that does not require internet access is preferable

3.2 Individual reading habits. We value the individual linguist's decisions as to what research questions could be interesting

(17) A GD should permit the reader to follow his or her own path to explore it.

(18) A short path between two related phenomena is better.

3.3. Familiarity. We value ease of access.

(19) A GD that is similar to other GDs known to the reader is better

3.4. Guiding. We value an informed presentation of the data.

(20) The GD should present the data in a didactically preferred way

3.5. Ease of exhaustive perception. We value the quest for comprehensive knowledge of a language.

(21) The readers should be able to know that they have read every page of the grammar.

3.6 Relative importance. We value the allocation of scarce resources of time to primary areas of interest.

(22) The relative importance of a phenomenon for (a) the language and (b) language typology should be retrievable.

3.7. Quality Assessment. We value indication of the reliability of analyses.

(23) The quality of a linguistic description should be indicated

3.8. Persistence. We value citability.

(24) In order to facilitate longterm reference, a grammatical description should not change over time.

3.9. Multilingualization. We value the interest of every human in a given language, especially interest from the speakers of the language in question.

(25) A GD should be available in several languages, among others the language of wider communication of the region where the language is spoken.

3.10 Manipulation. We value portability and reusability of the data.

(26) The data presented in a GD should be easy to extract and manipulate

3.11. Tangibility. We value the appreciation of a grammatical description as a comprehensive aesthetic achievement.

(27) A GD that can be held in the hand is better.