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Automatic generation of SGML content models

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SUMMARY

We study the problem of automatic generation of a document type definition (DTD) for a set of Standard Generalized Markup Language (SGML) documents. We present various situations where we have tagged documents but no DTD, and discuss the requirements various applications may have with respect to the generation process. We also present an automatic DTD generation tool that can be adjusted for several tasks necessary in the applications. The method is also demonstrated with some experimental cases.

KEY WORDS SGML Document type definitions Generation

1 INTRODUCTION

An SGML (Standard Generalized Markup Language) [1] document has both *tagging*, i.e. all its elements are marked with begin and end tags, and a *document type definition (DTD)* that describes the allowed structure of the document class to which the document belongs. The basic components of a DTD are *element declarations* that contain for each element a *content model* which in turn specifies the *model group* that defines the allowed content of the element. A model group is constructed of simpler model groups, *connectors*, and *occurence indicators*. The connectors — *Sequence* connector (","), *And* connector ("&"), and *Or* connector ("|") — specify the order of elements, whereas the occurrence indicators — *Optional* ("?"), *Required and repeatable* ("+"), and *Optional and repeatable* ("*") — specify how many times an element may occur in the position.

There are, however, situations, where we have tagged documents, but no DTD is available. For instance, we can convert documents from non-SGML environments by replacing typographical tags with SGML tags, but there is no similar source for the DTD. Creating a DTD manually is difficult, if the set of documents is large. Manual creation may even be impossible, for instance, if an online application reuses the results of some transformation process, the structure of which do not conform to any existing DTD. Clearly, there is a need for *automatic DTD generation*.

Automatic DTD generation has also been studied in [2,3,4,5], mostly in connection with some specific situations. We try to give an overview of the various cases where the need for a DTD may arise, and we also present our own method that has features adjustable for these cases.

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Assume we want to find a DTD for the following tagged dictionary entries [6].

```
<Entry><Headword>kaame/a</Headword> <Inflection>15</Inflection>
<Sense> kammottava, kamala, kauhea, karmea, pelottava </Sense>.
<Example_block> <Example>Kaamea onnettomuus, verityo. </Example>
<Example> Tuliaseet tekivat kaameaa jalkea. </Example>
<Example> Kertoa kaameita kummitusjuttuja. </Example>
</Example_block>
<Sense_structure> <Technical_field>Ark.</Technical_field>
<Example_block><Example>Kaamea hattu.</Example>
<Example> On kaamean kylma. </Example> </Example_block>
</Sense_structure> </Entry>

<Entry><Headword>kaameasti</Headword><Example_block>
<Example>Sireenit ulvoivat kaameasti.</Example>
</Example_block></Entry>

<Entry><Headword>kaameus</Headword><Inflection>40</Inflection>
<Example_block> <Example> Sodan kaameus.</Example>
</Example_block></Entry>
```

There are at least three trivial solutions for building the element declarations:

1. Find each element within the document, and allow it any content:

```
<!ELEMENT Entry                ANY >
<!ELEMENT Headword             ANY >
<!ELEMENT Inflection           ANY >
<!ELEMENT Sense                ANY >
<!ELEMENT Example_block        ANY >
<!ELEMENT Example              ANY >
<!ELEMENT Technical_field      ANY >
<!ELEMENT Sense_structure      ANY >
```

2. For each element find all the elements that appear within it, and form an optional and repeatable model group:

```
<!ELEMENT Entry            (Headword | Inflection | Sense
                            | Example_block
                            | Sense_structure)*>
<!ELEMENT Sense_structure  (Technical_field
                            | Example_block)*>
<!ELEMENT Example_block    (Example)*>
<!ELEMENT Headword         #PCDATA  >
<!ELEMENT Inflection       #PCDATA  >
 ...
```

3. De-facto grammar; take all the structures of the instances to be the DTD:

```
<!ELEMENT Entry            ((Headword, Inflection, Sense,
                             Example_block, Sense_structure)
                            | (Headword, Example_block)
```

```
                                  | (Headword, Inflection,
                                      Example_block)) >

<!ELEMENT Sense_structure (Technical_field, Example_block) >
<!ELEMENT Example_block   ((Example, Example, Example)
                           | (Example, Example) | Example) >
```

Solutions 1 and 2 are usually overgeneralizing, while solution 3 is too restrictive. A non-trivial solution should find a good compromise between these two extremes and capture at least some knowledge of the order of the elements, and whether the elements are optional, required, or iterating, like in the following:

```
<!ELEMENT Entry             (Headword, Inflection?, Sense?,
                             Example_block, Sense_structure?) >
<!ELEMENT Sense_structure   (Technical_field, Example_block)  >
<!ELEMENT Example_block     (Example)* >
```

Of course, we can ask whether we need non-trivial DTDs in the first place, since tagged documents may be used even without any DTD. For instance, we can make structured queries that just specify a string inside some element. However, it is certainly difficult for a user to get the most benefit from the structure, if s/he does not even know it. Many application programs, like editors and transformation tools, require a DTD. A trivial DTD may not be satisfying, if we, for example, have strong validation needs. In the next sections we discuss further the ways in which we can utilize automatical DTD generation. We also present the DTD generation tool we have implemented and show the results of some experiments that illustrate the use of our method in some application areas.

2 APPLICATIONS OF AUTOMATIC DTD GENERATION

Automatic DTD generation can be used for many purposes. The actual needs of the application determine how the generation has to be applied, and what kind of result we can expect. The needs can be examined along the following dimensions:

Complexity of the structure. If the structure of the document instances is simple, automatic DTD generation is easy and the quality of the result is good, i.e., we can easily achieve all the requirements stated below. Hence, in the following, we assume that the structure is somehow complex.

Time frame. We may have online applications that require immediate results. Sometimes we need the result quickly, and sometimes, e.g., in a design process, we have more time.

Need of completeness. The result either has to be a valid SGML DTD that is immediately usable within an SGML application, or the result is used as a source of information and hence may be a partial solution.

Need of rich structure. Some applications just need some DTD, thus a trivial solution that loses most of the structure may be appropriate. If a trivial DTD is not adequate, there is usually some tendency how much trivialization is preferred. If a DTD generation is used mainly to gather some information of the documents, the more structure can be discovered the better.

Need for readability. The resulting DTD may be used directly by some application program, hence the machine-readable form is adequate. Instead, if the DTD has to be understandable also by human users there are different requirements for readability.

Tagging can/cannot be modified. The source instances may be "given as such", i.e., there is either a fixed structure, or there is no time to modify the structure. On the other hand, for instance in a design process, the DTD generation can be used to reveal problems with the instance structures and tagging, which may be then updated according to the results.

Batch or interactive processing. Usually there is always first some kind of batch processing, which is followed by an interactive session if necessary, and if there is time and people for that.

In addition to the interactions already mentioned, these dimensions affect each other in several ways. The most important of these is: If the DTD has to be complete, and the structure is complex, we cannot get both full structure and readability, i.e., there has to be some trivialization. This is even emphasized, if the process has to be online, whereupon the user cannot simplify the result interactively.

There are at least two cases where the other dimensions do not affect the result, in addition to the first case mentioned, i.e., when the structure is simple. Clearly, if some trivial solution is adequate, we can always form it quickly, it is complete and readable, and there is no need to change the structure of instances. Similarly, if we do not require completeness, a somehow partial solution should be easy to generate. In the following sections we present applications that illustrate some combinations of the above-mentioned dimensions.

2.1 DTDs for static documents

Some document collections are "given as such", e.g. archives may have a very conventional structure that cannot be modified. Hence there is no need for a design process in the conventional sense, but the task is to find a DTD that makes it possible to use the documentation in the best possible way with SGML application programs. Moreover, with this kind of "historical" documents, which were never designed any grammar in mind, it may be very interesting to see the exact structure found in the documents. Hence, the discovery of the structure both has a meaning as such and gives extra information for various processing needs.

The second case of static documents are documents that come from some external source, e.g., messages imported to a company from outside. We may want to transform these messages to our own format, and for the transformation we need some DTD for the source documents.

2.2 Interactive design tool

Above we considered static documents. Quite in the contrary is the situation when we are designing our own document collection, e.g., all the documentation needed within our enterprise. In this case DTD creation is more or less similar to database design: modelling of the application area is needed. Now automatic DTD generation can be used as one design tool. If the planned documentation is based on existing documents, we can first

gather information from their structures and use it for evaluation and further design.

Assume we have used some non-SGML word processor for our documentation, and the writers have been obliged to use some common styles in a rigid way. Whenever we then want to convert the whole documentation to SGML, we might hope to get the DTD directly from the style rules. However, people do not necessarily obey the rules very strictly, since there is no way to make them obligatory. Therefore, when the documents are converted into SGML, it is useful to check what the real structure actually is. All the deviations of the rules might not be totally negative: there might be ways people have created to overcome some unexpected situations in the design process. Hence, the automatic DTD generation can reveal useful knowledge that can benefit the design of the new SGML documentation.

2.3 DTDs for different views and subdocuments

It is often wise to use some standard DTD. However, these DTDs are usually very large and designed to cover many varying cases. If we then need a simpler DTD for some task or a DTD for some subdocument, we can use automatic generation to find a DTD that accepts the selected documents. One example of this kind of DTD is an author DTD [7]: a DTD that is given to the people that create documents. For instance, in our research project [8] we have used ISO 12083 standard DTD for books [9] as a DTD for engineering text books. By now we have converted existing non-SGML books to this DTD, but since the conversion process is very tedious, the authors are recommended to use an SGML editor to create the new books. Hence, we need now a simpler DTD that the writers can use. We can utilize the already converted tagged textbooks to generate a DTD automatically, and check the result against the standard DTD to make the obvious generalizations, like allowing more than one author.

2.4 Online DTDs

We have studied in our research project [8] *intelligent assembly* of documents, which means that the user can configure new, individualized documents from a collection of documents and possibly also from external information sources. In document assembly, the basic operations are *queries* that return the selected fragments of documents, and *configuration* of these fragments to form sensible documents. Hence, the assembled document is a transformation of one or more existing documents. If, instead of simple printing of documents, we want that the resulting documents are valid SGML documents that can be reused later, possibly in assembling new documents, we need a complete DTD for them. These *online DTDs* have to be generated automatically. Of course, we can always use some trivial DTD, but if we want to get the maximal use of the assembled document, it is better to find a solution that is more structured.

We can form a DTD from the tagging of the assembled document, but this DTD may be too restricted. We are going to study, how the source DTD and the transformations can be used to generalize the target DTD in a suitable way.

3 AUTOMATIC DTD GENERATION

We have designed and implemented an automatic DTD generation tool (See [10] for a preliminary version and [11] for a detailed presentation of the implementation) that is

adjustable according to the above mentioned dimensions. In a typical session, there is a batch processing phase that produces the first complete candidate for a content model. The content model is a generalization of the source instances, but usually rather complicated. If the result is readable enough for the purpose of the application, there is no need for further processing. Otherwise, the continuation depends on the situation.

If we have an online application but still need a readable result, there has to be some further automatic generalization. This can be done by dividing the problem, e.g. with *isolating* some model groups, *trivializing* the result, or *discovering inclusions*. These further generalizations can be started every time after the basic part, or there may be some way to measure the complexity of the result, whereupon exceeding some given complexity threshold triggers the operations.

The above generalizations can be used even if we can afford interactive processing, although they can be applied more intelligently, since the background knowledge of the user can be utilized. For instance, we can try to discover inclusions automatically, but the result is better if the user can evaluate the candidates found and select the actual inclusions among them. If the automatic generation is used as a design tool, a useful operation is the *separation of common structures* from *exceptional* ones that generates a content model for both cases. This can give valuable information for the design process and may also cause updates in some instances.

3.1 Generating unambiguous content models

The basic idea of our method is to form for each element a deterministic finite automaton from the structures of the instances of this element, generalize these automata in a certain way, and then convert the automata to regular expressions that are easily written as SGML content models. The content models should be, according to the SGML standard, *unambiguous* in the following sense: A content model is ambiguous if an element or character string occurring in the document instance can satisfy more than one primitive token in the content model without look-ahead. An algorithm to check if a content model is unambiguous has been presented in [12]. Our method generalizes an automaton until its language is unambiguous according to the conditions given in [12].

3.2 Isolation of model groups

If the document structure is complicated, it is often useful to be able to introduce more nesting in the structure than present in the instances. For example in the dictionary entries seen in Figure 2 there are clearly elements that form the first part of the entry (e.g. *Headword (H), Inflection (I), Consonant gradation (CG)*) and others that appear at the end (e.g. *Sense (S), Example (E), Technical field (TF)*). Since both of these parts vary a lot, processing them separately reduces the complexity of the content models remarkably. The separation can be done by *isolating a set of elements* to form a new model group.

Consider the following element declaration:

```
<!ELEMENT Entry - - (Headword, Inflection,
                     ((Technical_field |
                       Consonant_gradation,
                          Pronunciation_instructions?),
                      (Sense, Example)*, Reference? |
```

```
                          Pronunciation_Instructions,
                          (Technical_field, (Sense, Example)*,
                           Reference? | Baseword))) >
```

If the elements appearing with the headword and the elements at the end are isolated we get the following simpler declarations:

```
<!ELEMENT Entry          - - (%Headword_part, %Rest_of_the_entry?>
<!ENTITY % Headword_part     "Headword, Inflection,
                              (Consonant_gradation,
                              Pronunciation_instructions? |
                              Pronunciation_instructions)? " >
<!ENTITY % Rest_of_the_entry "(Technical_field?,(Sense, Example)*,
                                 Reference? | Baseword)"  >
```

There are two ways in which the isolation of elements can be used in the structuring process. Above the new model group is defined as a parameter entity that can then be included in various other model groups as a kind of short-hand notation. Use of entities does not affect the document instances, but if elements are formed instead of entities, also the instances have to be updated. Then the isolation should generate a parser that can convert original documents to contain the new structures. The second way could be useful, if the isolation reveals that some essential structure is missing in the original documents.

The isolation process takes as input a set of elements (e.g. *Headword*, *Inflection*, *Consonant_gradation*, *Pronunciation_instructions* above) and a name for the new model group (*Headword_part*). All the occurrences of the elements to be isolated are found and a new model group is built for them. Finally the occurrences in the original model group are replaced by the given new name.

In batch processing, or if the user does not have any knowledge on the structure, it is useful if there is some way to discover the strongly related elements, i.e. the candidate sets for isolation, automatically. In our method we apply clustering.

To compute the clusters of elements we have to define some distance function for a pair of elements. The intuition behind our function is the following: elements *A* and *B* are close to each other if there is *AB* or *BA* in the instances and there are only few elements *C* such that *AC*, *CA*, *BC*, or *CB* appears. Also the number of times *AB* appears in the examples may be taken into account. Moreover, the distance between two clusters is the minimum distance between their elements.

After finding the best clusters the method can either proceed automatically, and isolate the elements of clusters as described above, or the clusters can first be presented to the user for evaluation. Similarly, the method can either create the names for the new entities or elements itself, or it can ask them from the user. Hence, the automatic isolation can be applied both in batch and interactive processing.

3.3 Inclusions

If some element appears more than once with many other elements, this element may be floating. Then it could be reasonable to interpret this element as an inclusion, since undiscovered inclusions may reduce the readilibity of the resulting content model remarkably. Examples of floating elements include footnotes, figures, and various cross-references.

To discover candidates for inclusions we simply count the number of elements that appear next to each element *A*. If the total number is greater than a given proportion of the whole number of elements, then *A* is considered an inclusion. After a possible check by the user, the inclusion element has to be removed from the content model and inserted in the set of inclusions.

3.4 Local trivialization

The whole generalization process attempts to find a solution somewhere in between the exact set of instances and the trivial case that contains all the structures. Basic generalization obtains some solution, but if it still contains too much variation, it can be further generalized. *Local trivialization* attempts to find the most complicated substructures, and generalizes them: if the complexity of some model group exceeds a given threshold, we form an optional and repeatable model group of all the elements included. Consider the following element declaration:

```
<!ELEMENT Entry - - (Headword,(Inflection,Consonant_gradation?)?,
                     Sense, ((Sense, (Technical_field | Example)?
                              | Example | Technical_field),
                     (Sense, (Technical_field | Example)? )*,
                     (Reference | Example) )? ) >
```

Here elements *Sense*, *Example*, and *Technical_field* appear in many combinations. If we trivialize the substructure containing them, we obtain the following declaration:

```
<!ELEMENT Entry - - (Headword,(Inflection,Consonant_gradation?)?,
                         ((Technical_field | Example | Sense)*,
                           Reference? )? )  >
```

3.5 Common and exceptional cases

Frequency information, i.e. how many times a certain structure appears in the instances, can be used for quantifying the importance of different types of structures for the element. At the moment our method can produce one content model for the common cases and one for exceptions, according to a given threshold. This knowledge can be used, e.g., for discovering errors and rare cases in the structures, which may lead to modifications in tagging, if that is allowed.

4 EXPERIMENTAL RESULTS

We have implemented the method described above, excluding the discovery of inclusions. In this section we present some experiments that illustrate how our method can be used to satisfy needs of varying applications.

4.1 Textbook

As mentioned earlier, we have converted one textbook into SGML and structured it according to our ISO 12083 -based DTD [9]. As we need a simpler DTD for the benefit of authors of new books, we generated a DTD for the book we already have, and now we can use this DTD as a basis for the author DTD. In Figure 1 we can see all the non-trivial element declarations resulted, i.e., the content models for all the elements seen on the right-hand side but not on the left-hand side are *#PCDATA*.

Our method produces a complete DTD, although in this case it is not totally necessary. After the basic generalization phase the method continued with local trivialization. It trivialized some model groups that have large variation, e.g. a part of the declaration for paragraph (*P*). All the processing was done without any interaction by the user.

4.2 Dictionary

Most challenging of our test cases has been the part *A* – *K* of a Finnish dictionary [6]. We converted the typographical tags of the dictionary, which consists of about 16000 entries, to structural tags, and obtained a set of 468 distinct structures. Every structure also received a frequency, i.e., the number of entries that the structure covers. We chose 55 of the most common structures (Figure 2), which together covered 14791 entries.

The dictionary was not originally designed for computer use, and therefore the structures of the entries have great variation. Even the editors cannot specify the desired structure for an entry. Hence, there is a strong need to gather information from the existing structures and use this knowledge to update instances to develop a more consistent structure. In this point this case differs from some otherwise similar cases, e.g., discovering the structure of ancient books or archives, where it is not desirable to change the structure.

Again, after the basic generalization with local trivialization the result was the following:

```
<!ELEMENT EN - - (H, ((EX|TF|S)*, R? | I, ( (EX|TF|S)*, R?
                  | CG, ((EX|TF|S)*, R? | (R,EX?) | PrF | (BW,EX)
                  | PaF, ((EX|TF|S)*, R? )? )?  | (R,EX?)
                  | PI, (S | ((TF|EX|S)*, R?) | R )?
                  | PaF, ((EX|TF|S)*, R? )? | PrF
                  | II, ((TF|EX|S)*, R? )? | (BW,EX))? | (R,EX?)
                  | PrF | PI, (S | (TF|EX|S)*, R? | R )?)?) >
```

This time we used some background knowledge, i.e., that elements *H*, *I*, *CG*, *PI*, and *II* form the first part of each entry. Therefore we made one interactive isolation step and obtained the following declaration:

```
<!ELEMENT EN - - (%HP,(( (EX|TF|S)*, R?) | (R,EX?) | PrF | (BW,EX)
                   | (PaF, (EX|TF|S)*, R? )?) )? ) >

<!ENTITY % HP     "(H, (I, (CG|PI|II)? | PI)? )" >
```

5 CONCLUSION

We have discussed the possible uses of automatic DTD generation tools, and which characteristics are needed from such tools in the applications. We introduced seven dimensions

```
<!ELEMENT ANSWER   - - (TITLE?, P, ( (P, FIGGRP? | FIGGRP)
                       (P, FIGGRP?)*, FIGGRP? )? ) >
<!ELEMENT APPENDIX - - (NO, TITLE, (P | (SECTION)*) >
<!ELEMENT APPMAT   - - (APPENDIX)* >
<!ELEMENT AUTHGRP  - - (AUTHOR, AUTHOR) >
<!ELEMENT AUTHOR   - - (FNAME, SURNAME | SURNAME, FNAME ) >
<!ELEMENT BACK     - - (BIBLIST) >
<!ELEMENT BIBLIST  - - (HEAD, (CITATION)*) >
<!ELEMENT BODY     - - (CHAPTER)* >
<!ELEMENT BOOK     - - (FRONT, BODY, APPMAT, BACK) >
<!ELEMENT CELL     - - (P) >
<!ELEMENT CHAPTER  - - (NO, TITLE, ((P)*, (EXAMPLE | FIGGRP)? )?,
                       (SECTION)*) >
<!ELEMENT CITATION - - (TITLE, (AUTHOR)*, (CORPAUTH)*, OTHINFO?,
                       DATE ) >
<!ELEMENT CORPAUTH - - (ORGNAME, CITY?) >
<!ELEMENT DFORMULA - - (#PCDATA | FIGGRP, FIGGRP?) >
<!ELEMENT DOCUMENT - - (BOOK) >
<!ELEMENT EXAMPLE  - - (P | TITLE, ((P | FIGGRP)*, ANSWER?)? ) >
<!ELEMENT EXERC    - - (NO?, ((P)*, (FIGGRP, P? | ANSWER)? )? ) >
<!ELEMENT EXGROUP  - - (TITLE?, ((EXERC)*, FIGGRP? )? ) >
<!ELEMENT FIGGRP   - - ((FIG)*, TITLE?) >
<!ELEMENT FOREWORD - - (TITLE, (P)*) >
<!ELEMENT FRONT    - - (TITLEGRP, FIGGRP, AUTHGRP, FIGGRP,
                       FOREWORD, PREFACE) >
<!ELEMENT ITEM     - - (P)* >
<!ELEMENT LIST     - - (HEAD, ITEM, (HEAD, ITEM)* | (ITEM)*) >
<!ELEMENT P        - - (#PCDATA | (DFORMULA | LIST | EMPH |
                       FORMULA | SUBSCR | SUPERSCR | FIGREF)*
                       (FIGGRP, FIGREF? | SECREF | SYMBOL)?
                       | FIGGRP | FORMREF | SECREF |
                       (SYMBOL, SYMBOL?)  | TABLE ) >
<!ELEMENT PREFACE  - - (TITLE, (P)*) >
<!ELEMENT ROW      - - (TSTUB?, CELL, CELL) >
<!ELEMENT SECTION  - - (NO, TITLE, ((P | EXAMPLE | FIGGRP | LIST)*
                       (EXGROUP, (SUBSECT1)* | DFORMULA |
                       (SUBSECT1)*)? | (SUBSECT1)* )? ) >
<!ELEMENT SUBSECT1 - - (NO, TITLE, ((P | FIGGRP | EXAMPLE)*,
                       EXGROUP?)? ) >
<!ELEMENT TABLE    - - (TBODY) >
<!ELEMENT TBODY    - - (ROW)* >
<!ELEMENT TITLE    - - (#PCDATA | (SUBSCR)*) >
<!ELEMENT TITLEGRP - - (TITLE) >
<!ELEMENT TSTUB    - - (P) >
```

Figure 1. A DTD for one textbook

2470	EN → H S	1787	EN → H EX
1325	EN → H	1122	EN → H I S
1056	EN → H S EX	1031	EN → H I S EX
995	EN → H TF S	574	EN → H I CG S EX
549	EN → H I TF S	387	EN → H I EX
352	EN → H I CG S	329	EN → H R
258	EN → H I TF S EX	232	EN → H TF S EX
195	EN → H TF	171	EN → H I R
138	EN → H I CG TF S	125	EN → H I
117	EN → H TF EX	100	EN → H PrF
97	EN → H I CG TF S EX	94	EN → H I PI S
92	EN → H EX S	85	EN → H I CG R
84	EN → H TF R	66	EN → H I S EX TF EX
54	EN → H I PaF S EX	53	EN → H I TF R
51	EN → H I CG S EX TF EX	47	EN → H I CG PrF
46	EN → H I CG BW EX	45	EN → H I S EX TF S EX
44	EN → H I PrF	44	EN → H PI S
42	EN → H I EX S	39	EN → H TF EX S
34	EN → H I PaF S	34	EN → H I CG PaF S EX
34	EN → H I PI TF S	31	EN → H I S TF S
30	EN → H I TF TF S	29	EN → H I II TF S
29	EN → H I S EX S	29	EN → H I BW EX
28	EN → H I CG S EX TF S EX	24	EN → H I CG EX
24	EN → H S EX S	22	EN → H I R EX
22	EN → H I PI R	22	EN → H TF TF S
21	EN → H R EX	21	EN → H S TF S EX
21	EN → H S EX TF EX	20	EN → H I CG R EX
20	EN → H EX TF S		

Figure 2. Sample dictionary structures

that affect the process of DTD generation: complexity of the structure, the time frame, the need of completeness, the need of readability, the need of rich structure, the possibility to modify the tagging, and the possibility to utilize interactive processing. Every application sets its own values for each of these dimensions, and thus determines how the DTD generation can proceed and which kind of quality can be expected from the result.

We also presented a generation tool we have designed and implemented, which offers features for several application areas. The tool produces unambiguous content models that — after the basic generalization phase — may be further processed with both interactive and batch operations. These operations include local trivialization of a model group, isolation of model groups, discovery of inclusions, and separation of common and rare cases.

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