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Knowledge for Understanding Table-Form Documents

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SUMMARY The issue about document structure recognition and document understanding is today one of interesting subjects from a viewpoint of practical applications. The research objective is to extract the meaningful data from document images interpretatively and also classify them as the predefined item data automatically. In comparison with the traditional image-processing-based approaches, the knowledge-based approaches, which make use of various knowledge in order to interpret structural/constructive features of documents, have been currently investigated as more flexible and applicable methods. In this paper, we propose a totally integrated paradigm for understanding table-form documents from a viewpoint of the architectural framework.

key words: *paradigm of document understanding, recognition of multi-kinds of documents, recognition of document class, classification tree, structure description tree, item sequence rule, item property frame, table-form document*

1. Introduction

The issue about document structure recognition and document understanding is today one of interesting subjects from a viewpoint of practical applications [1]-[3]. The research objective is to extract the meaningful data from document images interpretatively and also classify them as the predefined item data automatically. In comparison with the traditional image-processing-based approaches, the knowledge-based approaches, which make use of various kinds of knowledge in order to interpret structural/constructive features of documents, are currently investigated as more flexible and applicable methods. The approach that interprets reasonably document images with the knowledge about document-specific applications, document composition rules, document layout structures and so on is regarded as an application of artificial intelligence techniques, and is applicable to various kinds of documents intelligently though the traditional approaches, based on the image processing techniques, were effective to only very limited document structure. Namely, the knowledge-based approach supports a global processing paradigm for analyzing/understanding documents in comparison with the local processing methods of image-processing-based approaches.

Until today, many knowledge-based approaches have been reported with respect to the issues about the document structure recognition and document understanding. The methods proposed in these knowledge-based approaches are roughly divided into two groups in point of knowledge specification means: rule-oriented methods [4]-[6] and frame-oriented methods [7]-[10]. These methods are selective for document types, which characterize the applications/forms of documents [1]-[3]. For example, the rule-oriented method is applicable to some kinds of documents, in which the composite items are allocated under the mutual relationships by logical structures: newspapers [11]. While, the frame-oriented method is successful for documents, in which the composite items are controlled strictly by geometric layout structures: name cards, business letters, official documents, library cataloging cards and so on. However, these approaches had not always attached to the research subjects about the flexibility, applicability and adaptability for the document structure recognition and document understanding sufficiently, though they made the fundamental framework clear. It is important to investigate various classes of problems, that were derived from currently developed recognition methods but have never been assessed sufficiently from a practical point of view.

In this paper, we propose a totally integrated paradigm for understanding documents with respect to the management for various kinds of document knowledge, and also address the recognition/understanding methods of table-form documents from an architectural point of view.

2. Framework of Document Understanding

Documents may be classified into several document types, depending on the mutual relationship between logical structure and geometric layout structure [1]-[3]. It is very difficult to develop document recognition/understanding methods which can interpret all types/kinds of documents applicably. Thus, many of knowledge-based document understanding systems, which have been developed until today, were applicable to only application-specific documents, because the knowledge adaptable to the analysis/recognition of documents is collected from the peculiar domain. For

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example, documents with different layout structures or different logical structures such as newspapers and business cards can not always be distinguished by the same methods successfully [1], [2]. In order to accomplish such a task we need to recognize the document class or document type. Here, we define the document type as a classification of documents, which is decided on the basis of the mutual relationship between logical structure and geometric layout structure [1], [2]. Also, the document class is defined as a group of documents, which can be distinguished by the same layout knowledge from a document type. In this paper, we address mainly the document class recognition, but not the document type recognition because it is in general more difficult to recognize the type than the class. We can illustrate such a framework for understanding documents conceptually in Fig. 1.

This framework is organized as an enhanced version of our three-layer recognition paradigm: layout recognition, item recognition and character recognition [12], [13]. The layout recognition procedure identifies the geometric and spatial relationships among item blocks, which are sets of meaningfully allocated item fields, in 2-dimensional space. The item recognition procedure distinguishes individual item data from the item blocks in 1-dimensional space. Finally, the character recognition procedure extracts each character pattern, which composes individual item data, and transforms from the extracted character patterns to the corresponding character codes in 0-dimensional space. These three recognition procedures interact mutually: the higher-level recognition procedure assists the lower-level recognition procedure by distinguishing processing objects meaningfully; and the lower-level recognition procedure feeds back the control to the higher-level recognition procedure in order to instruct the retrial recognition, when it found out some contradictions between the propagated processing objects and its own knowledge. The new framework in Fig. 1 is refined progressively with respect to the flexibility, applicability and functionality for recognition of various classes of documents. Namely, our newly refined framework is more general and applicable than our old framework.

The document class recognition procedure classifies various kinds of documents into individual

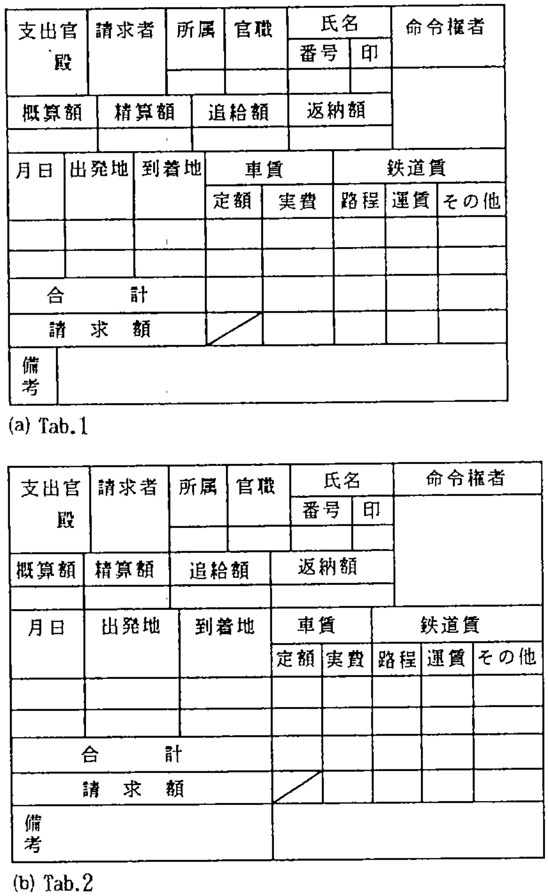

Fig. 2 Examples of table-form documents.

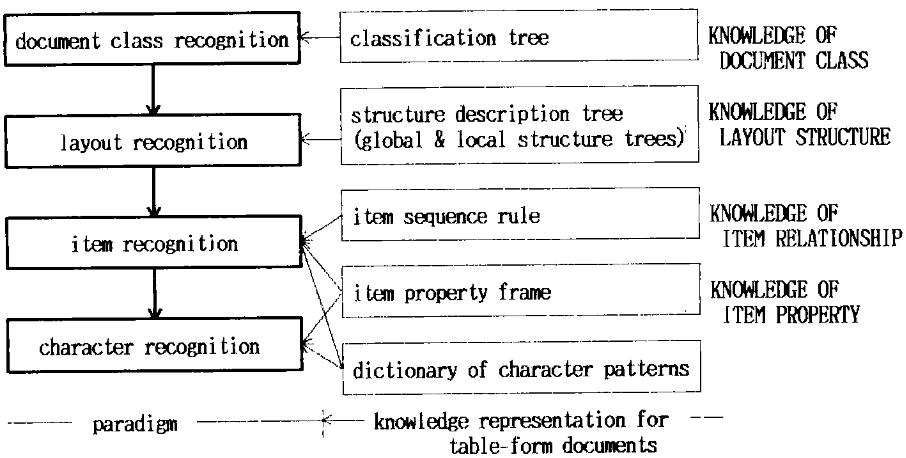

Fig. 1 Framework of document understanding.

document classes, which can be interpretatively identified by the same knowledge about layout structures. For example, consider two table-form documents in Fig. 2. These geometric layout structures are different, but the logical structures are the same. The document class is defined as a set of documents whose geometric layout structures can be uniquely identified by the same knowledge about organizational relationships among horizontal/vertical line segments. Therefore, two table-form documents in Fig. 2 should be classified as the same document class if the applications are the same. Of course, the knowledge must be represented only by the logical information in order to identify them as the same document. Here, the logical information is specified as the constructive relationship among document items, but does not include any coordinate values such as positions, lengths, sizes and so on. Until today, the researches about document structure recognition and document understanding have not always attached to this subject. This is partly because this recognition subject is very difficult, and partly because the current technical subjects focus mainly on the practical methods for understanding application-specific documents. However, the issue on the document class recognition is important in case of managing many different documents at once because many kinds of documents may be available in application-specific forms.

3. Knowledge of Table-Form Document

Table-form documents, whose individual item fields are always surrounded with horizontal and vertical line segments, are geometrically designed on the basis of layout structures [14], [15]. These item fields are not independent with each other, but are related mutually. So, the hierarchical structure and repeating structure, as parts of table configurations, are composed of several interdependent item fields. Table-form documents are well specified through the layout structures in comparison with other kinds of documents such as library cataloging cards, name cards, business letters, newspapers and so on, because each composite item is predefined rigidly. Therefore, in analyzing the document structures it is better to extract vertical and horizontal line segments firstly and then identify each item by interpreting the neighboring relationships among item blocks/item fields, surrounded with line segments.

Many researches proposed on the document understanding and document structure recognition make use of the physical information about document forms, as knowledge. The knowledge, based on the physical information such as positions, sizes, lengths and so on, is not always useful for reduced/expanded documents, irregularily transformed documents, and documents which are inconsistent to the geometrically predefined structures, even though it is adjustable to documents with the same geometric layout structure. It is very important that the knowledge should be specified by only the logical information in order to be applicable to various documents, which are consistent to the logical relationships among items (or item fields) [1]-[3]. If the knowledge represents the logical relationships among items (or item fields), documents can be interpreted applicably and flexibly. For example, two table-form documents shown in Fig. 2 are different because their coordinate values of individual item fields do not match well from a viewpoint of geometric layout structures. However, these table-form documents are the same with respect to the logical structures.

In addition to the relationships among individual recognition procedures, Fig. 1 shows the corresponding knowledge. In our framework for understanding table-form documents four kinds of knowledge is useful under individual knowledge representation means.

(1) Knowledge of document class

The knowledge must be able to categorize many different documents effectually into document classes so that appropriate knowledge about geometric layout structure can be furthermore applied to the distinguished document classes. This knowledge can be represented with a multi-ways tree in our approach. We call this tree as the classification tree. The node corresponds to each document class, and indicates the knowledge representation of geometric layout structure to be adaptable to this class. While, the edge represents the interdependent relationship between a parent document class and a child document class. Namely, child document classes are derived stepwisely from the parent document class. For example, in Fig. 3 we illustrate the classification tree for several table-form documents shown in Fig. 2 and Fig. 4. The marked nodes indicate document classes for 8 kinds of table-form documents in Fig. 2 and Fig. 4. Tab. 3 and Tab. 6 are derived from Tab. 5, respectively.

This tree grows up when another table-form document, which is not consistent to the existing document classes, is newly added. The new node for an additional table-form document is attached to the node associated with the most similar layout structure for the existing document classes. Namely, the nodes in our classification tree are distinguished by the ordered collections of the number of vertical or horizontal line segments which separate individual item partitions stepwisely from outer blocks to inner blocks [16]. The block division process is illustrated in Fig. 5. In Fig. 5, the right side is furthermore divided in comparison with the left side by vertical or horizontal line segments which connect to the edges of item partitions. The left side is transformed into the upper node, while the right side is done into the lower in our

資料請求カード

会 社 名	製 品 名	送付ご希望の欄に○印をつけて下さい			
		カタログ	技術データ	価格表	その他

(a) Tab.3

資料請求記入表

勤務先			
部課・ 役 職			
所在地			
ご芳名		電話	

(b) Tab.4

下記会社のカタログ・資料を請求いたします。

会社名または掲載頁	月号	製 品 名

(c) Tab.5

物品使用簿

品 目			規 格		数量	記号	番号
使用開始 年 月 日	使用者氏名	印	返 戻 年月日	供用官 受領印	設置場所		
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(d) Tab.6

カタログ・資料請求カード

氏 名 (フリガナ)		年令	
勤務先住所			
勤 務 先			
所 属 名		電話番号	

(e) Tab.7

物品管理簿・出納簿(消耗品)

整理	分類	細 分 類		種 類 別			記号	番号	物品管理簿 物品出納簿 記帳			
									物品供用簿 記帳			
異動記録	年 月 日	整 理 区 分		摘要	異動数量			現 在 高			備考	
		物品管理官	物品出納官		増	減	その他	貸付寄託	保管	計		

(f) Tab.8

Fig. 3 Other examples of table-form documents.

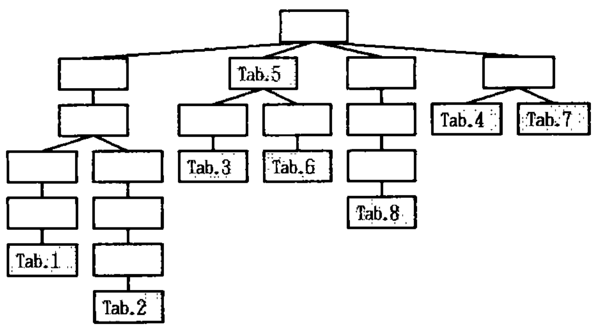

Fig. 4 Classification tree.

classification tree. Of course, this block division process generates various branches, according to the number of vertical or horizontal line segments to be applied stepwisely. We show the search procedure for our classification tree in Appendix.

(2) Knowledge of layout structure

This knowledge must distinguish individual item fields under the constructive relationships. The knowledge for table-form documents is represented by the structure description tree (as a binary tree). Our structure description tree indicates the adjacent relationships among item blocks and the connective relationships among item fields, but not the coordinate values of items. Namely, this tree deals with only logical information about document structure. The structure description tree is divided furthermore into the global structure tree and local structure trees. The global structure tree represents the global feature for the whole layout structure of table-form document: repeating structure, hierarchical structure, array-form structure and adjacent structure among item blocks. The

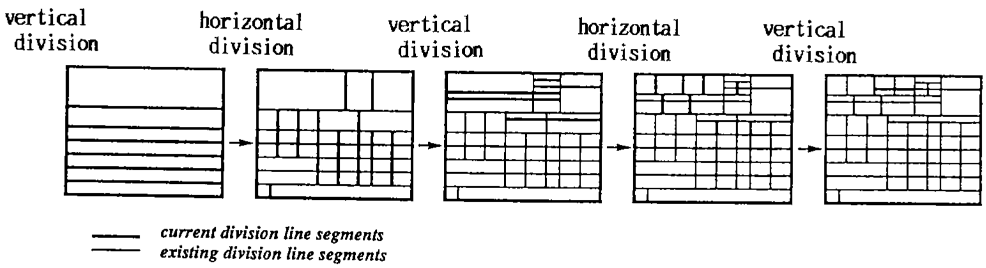

Fig. 5 Block division process.

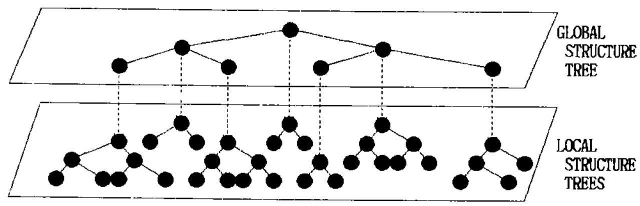

Fig. 6 Structure description tree.

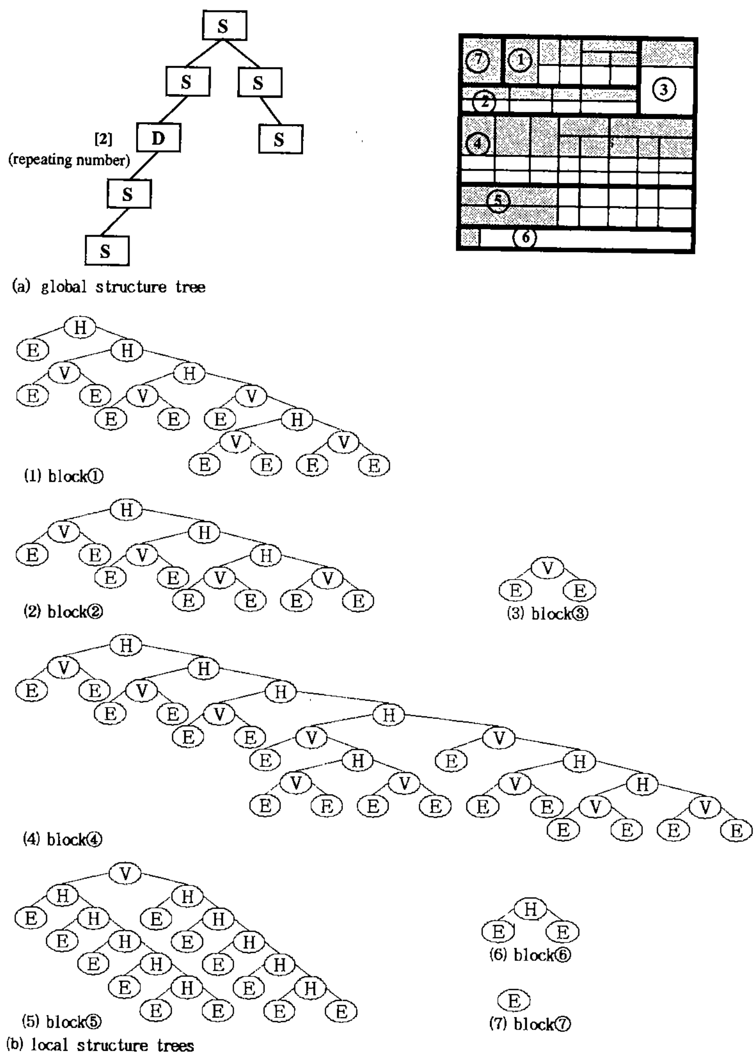

Fig. 7 An example of structure description tree.

nodes point out individual item blocks, and the edges correspond to the adjacent relationships among item blocks.

While, the local structure tree represents the detail structure for individual item blocks, which are distinguished by the global structure tree. Namely, the local structure trees are attached to each node in the global structure tree, and represent the connective relationships among item fields, which are included in each item block. The nodes indicate individual item fields (or item blocks), and the edges correspond to the connective relationships among item fields (or item blocks). Figure 6 shows the relationship between the global structure tree and local structure trees, conceptually. For example, consider a table-form document in Fig. 2(a). Figure 7(a) is the global structure tree, and Fig. 7(b) is the local structure trees. In Fig. 7(a), the notations attended to each node point out the node types: "S" shows that the corresponding item block is a simple structure; and "D" does that the corresponding item block is a repeating structure. And also, in Fig. 7(b) the symbol "H" indicates that the corresponding item block is partitioned vertically; "V" does that the corresponding item block is separated horizontally; and "E" does that the corresponding item block is not furthermore divided as an item field. The structure description tree in Fig. 7 is also applicable to Fig. 2(b) though it was originally generated from Fig. 2(a). This is because this tree includes only the logical information for the layout structure.

(3) Knowledge of item relationship

The knowledge must distinguish individual item data with respect to the combinative relationship among items. This knowledge is represented by the item sequence rule. The item sequence rule is applicable to the separation of individual item data, because each item field does not always contain only single item but may be composed of several compound items. For example, we consider the data "Furo-cho, Chikusa-ku, Nagoya 464-01" (This represents our university address). This address data is composed of several item data, which are separated basically by the symbol "," or " " (blank): "Furo-cho", "Chikusa-ku", "Nagoya" and "464-01", and they have the predefined sequence as the order such as ⟨machi-name⟩, ⟨ku-name⟩, ⟨city-name⟩ and ⟨zip-code⟩.

The general syntax form is as follows:

⟨rule⟩ : : =⟨rule-name⟩ : ⟨item-sequence⟩

⟨item-sequence⟩ : : ={⟨item-sequence⟩|}⟨item⟩

⟨item⟩ : : =⟨item-name⟩[⟨property⟩]

⟨property⟩ : : ="optional" | "mandatory"

Here, "optional" denotes that the attended term may be abbreviated, and "mandatory" does that the term must be always assigned. These item data are inherently dependent as composite data. Generally, these mutually related items are specified by the item sequence rule. In table-form documents, this item sequence rule is very simple, because each item field includes only single item in many cases.

slot name	slot values
NAME	zip-code
SEPARATOR	","
LENGTH	(3,0) or (3,2) by "-"
CHARACTER SET	numeric
OCCURRENCES	single
CANDIDATES	------
LOCATION	before "city"
DICISION CONDITION	LENGTH & NUMERIC ....

Fig. 8 Item property frame "Japanese zip-code".

(4) Knowledge of item property

The knowledge specifies various characteristics of item data in order to distinguish them from the other item data clearly. Also, this is represented by the record structure and is called as the item property frame. This item property frame accommodates various information such as kinds of character sets, lengths of character strings, occurrences, keywords as separators, candidate data, decision condition and so on into its composite slots, together. For example, consider "464-01" as the zip-code. The item property frame is shown in Fig. 8. The item sequence rule is cooperated effectively with this item property frame in the item recognition procedure. Namely, the composite items of the item sequence rule are meaningfully defined in the corresponding item property frames. Also, this item property frame can assist the character recognition procedure effectively such that candidate item characters are assigned to the candidate slot.

4. Relationships among Knowledge Structures

These various kinds of knowledge is mutually related: these four-level knowledge constructs a hierarchical structure, corresponding to the interdependent relationship among four-layer recognition procedures. For example, the knowledge of document class is an upper-level knowledge to apply knowledge of an appropriate layout structure to table-form document images. The knowledge of layout structure is an upper-level knowledge to distinguish individual item fields so as to be able to separate meaningful item data effectively by knowledge of item relationship. Similarly, the knowledge of item relationship is on the upper-level for knowledge of item property, and the knowledge of item property is on the upper-level for dictionary of character patterns.

(1) Relationship between classification tree and structure description trees

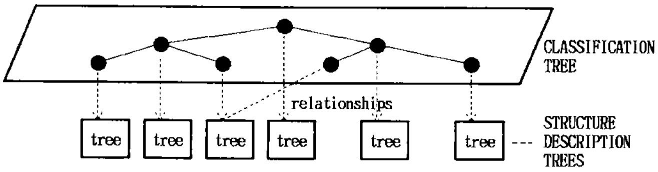

Fig. 9 Relationship between classification tree and structure description trees.

The classification tree distinguishes document classes, and manages various kinds of layout structure knowledge. The nodes in the classification tree are organized systematically on the basis of the physical characteristics, as shown in Fig. 5. Therefore, two table-form documents, which are designed under the same logical structure: Tab. 1 and Tab. 2 in Fig. 2, are not always classified into the same node, like Tab. 1 and Tab. 2 in Fig. 4. Of course, our structure description tree in Fig. 7 is applicable to these two table-form documents Tab. 1 and Tab. 2, because the structure description tree represents only the logical information of table-form documents on the basis of adjacent/connective relationships among item blocks or item fields.

In order to manage the storage for knowledge representation effectively, such duplication phenomena for the correspondence between nodes in the classification tree and structure description trees must be avoided. It is easy to manage the classification tree effectually because the block division process is based on only the number of vertical and horizontal line segments. Therefore, it is necessary to check up all the structure description trees when a new node is added to the classification tree. This procedure works easily and rapidly because the practical checking mechanism is executed in accordance with two steps: the first is done in the global structure tree; and the second is so in the local structure trees. If two layout structures are different globally, the checking procedure is aborted in the global structure tree. Figure 9 shows the relationship between classification tree and structure description trees.

(2) Relationship between structure description tree and item sequence rules

The structure description tree distinguishes individual item fields, which may contain one or more item data. The item sequence rule is applicable to item sequence in such partitioned item fields. Of course, when the partitioned item fields contain only one item, the item sequence rule is not effective. The item sequence rules are attached to the nodes in the local structure trees, if necessary. Figure 10 shows the relationship between structure description tree and item sequence rules.

(3) Relationship between item sequence rule and item property frames

The item sequence rule represents the combinative sequence among meaningful items, while the item property frame indicates the characteristics of item

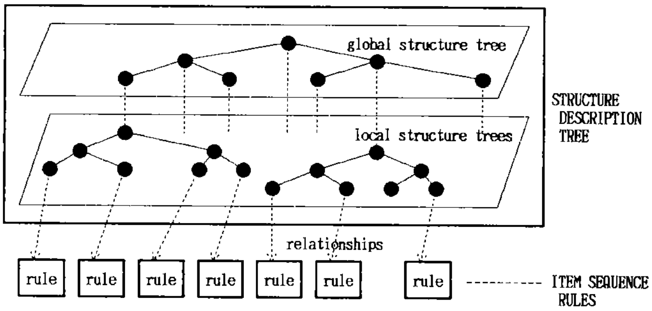

Fig. 10 Relationship between structure description tree and iteme sequence rules.

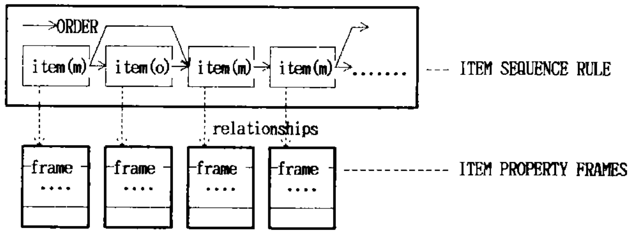

Fig. 11 Relationship between item sequence rule and item property frames.

forms. The item recognition procedure can distinguish individual item data successfully with item sequence rule and item property frame. The item property frames are attached to items, which compose the item sequence rule, one by one, as shown in Fig. 11.

(4) Relationship between item property frame and character pattern dictionary

The item property frame contains several candidate character strings in the candidate slot, if possible, and specifies several constraints in the slots such as the length, character set, occurrences and so on. These information can assist the selection way when the character recognition procedure extracts an appropriate character pattern from the dictionary.

5. Conclusion

In this paper, we proposed a framework of four-layer recognition procedures for understanding documents and addressed the knowledge representation method, adaptable to the understanding of table-form documents. Until today, the recognition of document class has not always been focused on as one of the research subjects. Although Nakano et al. looked upon the recognition of multi-kinds of table-form documents as an important subject from a practical point of view [7], they could not report any successful approach because their knowledge was based on only the physical coordinate data. In our approach, this recognition issue was solved completely, using the classification tree based on the physical characteristics of table-form documents, and the structure description tree based on the logical characteristics of table-form documents. At least, it is not so difficult to classify various kinds of documents into appropriate document classes since table-form documents are well designed on the basis of vertical and horizontal line segments. However, it is not easy in case of the other documents because the geometric and spatial characteristics of documents are not well specified. It is necessary to investigate the document class recognition techniques for the other documents or document type recognition methods from a viewpoint of the knowledge representation.

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Appendix

The following procedure is an algorithm to classify documents:

Initial states: $k=0$, $Q=$' ', $q=p$.

1. addqueue (F_0, Q).
2. addqueue (F_1, Q).
3. F: $=$first (Q).
4. Compute pixel distributions for "F" in X- and Y-axes. And then extract candidates from vertical and horizontal line segments.
5. Select candidates, whose terminals connect to most outer surrounded line segments of "F". And then set number of horizontal line segments to variable "i" and number of vertical line segments to variable "j".
6. **if** $i \neq 0$ or $j \neq 0$, **then** insert (i, j) into "$node_k$", and also add regions which were divided by line segments to "Q".
7. F: $=$first (Q).
8. **if** $F \neq F_1$, **then goto** 4.
9. If appropriate nodes are not found out after having searched classification tree by following procedure, connect "$node_k$" to classification tree.

   if $p \downarrow .ps = NULL$ **then** $\{p \downarrow .ps := \&(node_k); p := \&(node_k)\}$

   else$\{p := p \downarrow .ps;$

   while $p \downarrow .data \neq node_k$ and $p \neq NULL$ **do**$\{q := p; p := p \downarrow .pt\}$

   if $p = NULL$ **then**$\{q \downarrow .pt := \&(node_k);\ p := \&(node_k)\}\}$
10. **if** $Q=$' ', **then** Finish.
11. $k := k+1$, addqueue (F_1, Q), **goto** 7.

Here, "Q" is a queue to record regions, which are recursively divided by horizontal and vertical line segments, until every item field is identified. Additionally, "Q" has coordinate values to represent the left-upper and right-lower points of divided regions. The coordinate values are denoted by "F": in particular, "F_0" corresponds to the largest region, surrounded with outer line segments of table-form document. Moreover, "F_i" is an indicator for the region, generated by a division. The node in the classification tree is composed of a record of three elements: $(ps, pt, data)$. "ps" is an indicator for the most left node; "pt" is an indicator for the brother nodes; and "$data$" is (i, j). "p" and "q" indicate to search the classification tree, and point out the root node of the classification tree initially. "*addqueue*" is a procedure to add an element to "Q". "*first*" is a procedure to take out the first element from "Q". "&" is a procedure to compute the address of parameter, and "$node_k$" represents a k-level node of the classification tree.

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