The Skeleton Document Image Retrieval System

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Abstract

This paper describes Skeleton, a document image retrieval system whose design and implementation is based upon image analysis and document retrieval technologies incorporated in the IDUS image understanding system and the INQUERY information retrieval system, respectively.

Most of the current Skeleton development effort has been put into establishing indexing and query formulation methodologies in which both words and character subsequences of words (ngrams) are tokenized.

A Web-based interface has been developed for Skeleton which includes a Java image display applet to support word and region highlighting.

1 Overview

The Skeleton architecture supports document image analysis, indexing, and retrieval. The indexing component assumes an image analysis in which text regions are grouped into articles with head and body relations identified and text recognized using conventional OCR technology. Functional role distinctions such as *dateline* and *caption* are not taken advantage of in the current implementation but in future versions of the system they will be used to extend fielded search capabilities.

Both the OCR text output of an indexed unit of text and the corresponding page image containing it can be retrieved by Skeleton. It is assumed that end users will normally want to retrieve page images with appropriate regions highlighted and pointers to other pages of the same document provided. However, our experience has indicated that access to the OCR text output is useful in the search process.

In the next two sections, additional information about the image analysis process incorporated into Skeleton from the IDUS system and the system's basic retrieval capabilities inherited from the INQUERY system are described [1,2]. Following this discussion, Skeleton's Web-based interface is illustrated.

2 Document Image Analysis in Skeleton

Skeleton's image analysis component, which was originally developed for use in the IDUS system, is illustrated in Figure 1.

The image analysis component includes Scan*WorX*, a commercial product developed by Xerox Information Systems which provides segmentation and OCR support.

Image analysis modules developed specifically for use in IDUS which have been incorporated into Skeleton include a logical analyzer, a document classifier and a functional analyzer.

The IDUS image understanding system from which these modules were borrowed provides a sophisticated X-windows user interface for examining image analysis output in a graphical form. Although the IDUS interface is not a component of Skeleton, the ability to use IDUS to evaluate image analysis performance is an attractive option.

2.1 Scan*WorX* Modules

Since Skeleton relies upon Scan*WorX* to perform the initial segmentation of document images, it inherits that component's image input constraints. For Scan*WorX* to work properly, image resolution must be 200x200 dpi, 200x100 dpi, 400x200 dpi, or any RxR (square) dpi resolution, where $250 \leq R \leq 450$.[1] Scan*WorX* requires images to be black text on a white background for the OCR module to work properly. It is possible for the system to invert images which are white text on a black background, but color images need to be preprocessed into a proper format. Although a variety of image input formats are

[1] The Scan*WorX* OCR module can recognize text in images whose resolutions range from fax to 600x600 dpi, but for resolutions outside the previously mentioned ranges, manual segmentation is necessary. Since image analysis in the Skeleton architecture is expected to be an automated process, the system is constrained to processing images in the previously mentioned resolutions.

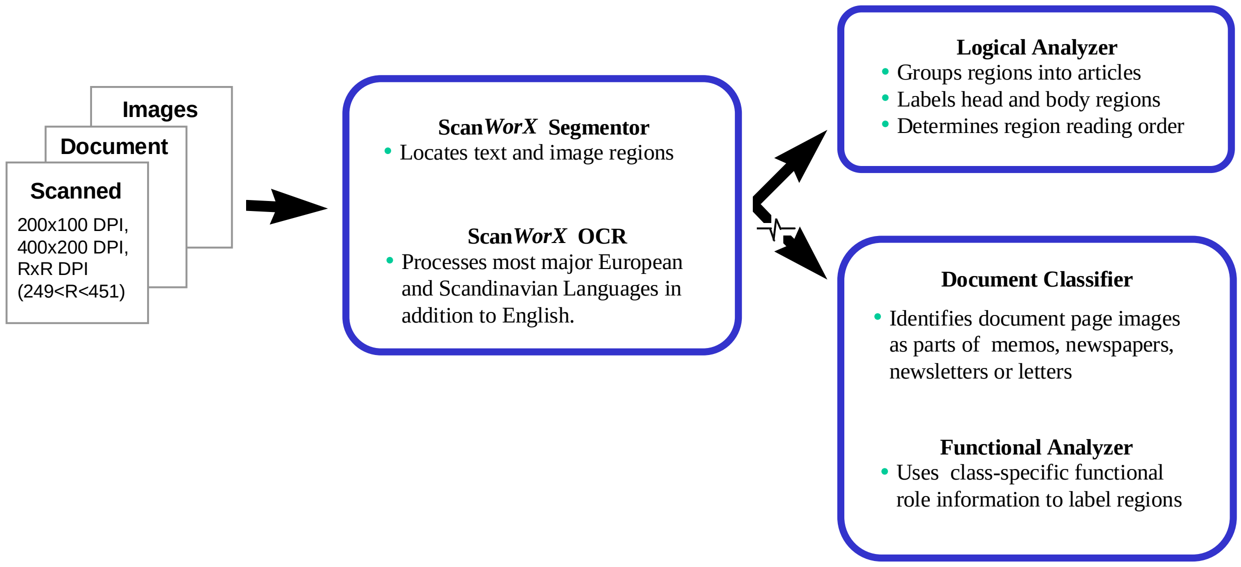

Images
Document
Scanned
200x100 DPI,
400x200 DPI,
RxR DPI
(249<R<451)
Scan*WorX* Segmentor
• Locates text and image regions
Scan*WorX* OCR
• Processes most major European and Scandinavian Languages in addition to English.
Logical Analyzer
• Groups regions into articles
• Labels head and body regions
• Determines region reading order
Document Classifier
• Identifies document page images as parts of memos, newspapers, newsletters or letters
Functional Analyzer
• Uses class-specific functional role information to label regions

Figure 1: Skeleton's image analysis components are capable of providing a rich array of information about document structure and content. In the current implementation of Skeleton, information about logical groupings of regions into articles is used to build a document collection. Document class and functional role information is not yet being used in the prototype, but will be incorporated in future implementations to further extend user options in fielded searches.

supported by Scan*WorX*, Skeleton development has been based solely upon the analysis of images in TIFF format.

The Scan*WorX* segmentation module identifies text and image regions within a document page image. Regions cannot span page boundaries, but can overlap one another.

The Scan*WorX* OCR module is capable of processing most major European and Scandinavian languages in addition to English [4].

The segmentation module provides a listing of the regions which have been identified, with the location of each region described in terms of four integers: the first two integers represent *X-Y* coordinate values and the second two represent the width and height of the region, respectively. The type of the region is also specified.

Separate output files are written which contain the OCR results for each text region. To support highlighting in retrieved images a Xerox proprietary output format called XDOC is used which represents information about the location of characters in a document page image, as well as character and word recognition confidence scores.[2]

[2]The character and word recognition confidence scores are not yet being used in Skeleton. In future work on the system, experiments which factor this information into the search process will be conducted. For more information on the XDOC format, see [5].

2.2 Logical Analyzer

The segmentation of a document page image into regions defines a *geometric* tree structure, and the goal of the logical analyzer is to derive from this geometric tree structure a *logical* tree structure which identifies clusters of regions functioning as articles. This process involves the labeling of regions as *head* and *body* constituents: head regions are interpreted as titles and body regions are interpreted as constituent columns of text. An important by-product of logical analysis is the determination of reading order. The analysis method used by this module is influenced by the work of Tsujimoto and Asada [6].

Output data provided by the logical analysis component includes a sequence of entries which describe the text regions delimited by the segmentation module. Each region is described in two such entries, one which describes its role in the geometric tree structure, and one which describes its role in the logical tree structure. These entries declare an index for a region and indicate if it plays a head or body role in the specified tree.

A listing of geometric and logical tree node descriptions is also provided in the component's output. Each node listing contains an integer value specifying how many regions are subsumed by the node followed by the indices for those regions. The reason for the indices declared in the text region entries is to facilitate this cross referencing.

During logical analysis, text regions which have been determined to be in the same column and exhibit some vertical overlap are merged into a single, composite region. A listing of such mergers is provided in the logical analysis component's output.

2.3 Document Classifier

The document classification module is currently able to distinguish business letters, memos, newspapers, and newsletters.

It is possible to stipulate a document class when Skeleton is asked to process a collection of document images. This is often a useful feature, since in many cases a document image collection consists of documents which are of the same type.

2.4 Functional Analyzer

Like the logical analyzer, the functional analyzer relies upon the segmentation module to identify text and image regions. However, unlike the logical analyzer, it also is dependent upon the document classifier. Given knowledge about the possible functional roles played by regions in documents of a given class, the functional analyzer attempts to infer the functional roles played by the regions which have been identified by the segmentation module.

Two different functional analysis methodologies have been implemented:

1. A *content-based* approach which focuses on the string matching of keywords associated with particular components and is thus dependent on good OCR accuracy
2. A *geometric-based* approach, which is OCR independent and relies only upon segmentation and document classification.

Evaluations involving English language business letters have shown that the geometric approach executes almost twice as fast as the content-based approach on the same document with little degradation in performance. However, since Skeleton relies upon OCR processing for document indexing anyway, the better processing speed of the geometric-based approach cannot be taken advantage of, and given that this is true, pursuing a content-based functional analysis methodology is more appropriate, since this method permits a richer document representation which may prove useful in future evaluations of functional analysis performance involving larger collections of document images and a greater variety of document classes.

The output of functional analysis includes an indication of the class of a document and a listing of regions associated with functional labels.

During functional analysis, as in logical analysis, one or more text regions identified by the segmentation module may be merged into a single, composite region. However unlike logical analysis, it is also possible that a single region may be split into multiple regions which are assigned different functional roles. A listing of any mergers or splits is provided in the functional analysis component's output.

3 Document Image Retrieval in Skeleton

Skeleton's information retrieval capabilities inherited from INQUERY are used to build a database of article-sized document representations in which the head and body components of each article recognized by the logical analysis component are labeled with SGML-style `TITLE` and `TEXT` tags. Fielded searches on the `TITLE` and `TEXT` fields within these article-sized documents is supported.

3.1 Indexing Terms using Ngrams

Most of the current research effort on the Skeleton project has been put into the development of an appropriate indexing methodology which takes into consideration the possibility of poor OCR text output without assuming that OCR output will always be poor.

To reduce the degradation in retrieval performance caused by high OCR error rates, image analysis text output is indexed using combinations of full word tokens and a sampling of word token character sub-sequences (`ngrams`). Which particular collection of `ngrams` to extract from a word token is an empirical question now being explored.

In the current implementation an ordered sequence of two, three, four and five-character `ngrams` is extracted, but to reduce the size of the document database a subset of at most eight `ngrams` are selected for indexing purposes.

If the number of `ngrams` in the ordered sequence extracted from a given word token is less than or equal to eight, then all are retained for indexing. Otherwise, the `ngrams` selected for inclusion in the subset are the leading three, the final two and three from "the middle". Letting N represent the number of `ngrams` in an ordered sequence, the first of the "middle" `ngrams` is in position $((N-4)/3)+2$, the second is in position $((N-4)/2)+2$ and the third is in position $(((N-4)/3)+2) \times 2$. The positions of `ngrams` in an ordered sequence are counted beginning with 0, not 1. Figure 2 illustrates this method for determining a subset of `ngrams` to use in document indexing.

The position declared for an `ngram` token in the document database is the same as the position of the word token from which it has been extracted (not its position in the ordered sequence of `ngrams` extracted from the word token). Given that this is the case, an effort is made to replace any duplicate `ngrams` which might arise in the subset selected for indexing once the above method has been used to identify them. The key issues in selecting a subset of `ngrams` is to be consistent and to attempt to arrive at a representative sample.

Example word token: *mexican*

Ordered sequence of two, three, four and five-character ngrams:

me mex mexi mexic ex exi exic exica xi xic xica xican ic ica ican ca can an

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
17

Ngrams retained for indexing:

Leading three ngrams at positions 0, 1 and 2	→	me mex mexi
Trailing two ngrams at positions 16 and 17	→	can an
First of "middle three" ngrams at position $((N-4)/3)+2 = 7$, where $N=18$ and division of 14 by 3 is rounded up	→	exica
Second of "middle three" ngrams at position $((N-4)/2)+2 = 9$	→	xic
Third of "middle three" ngrams at position $(((N-4)/3)+2) \times 2 = 14$	→	ican

Figure 2: Method for determining which ngrams of a word token to select for indexing

3.2 Query Formulation

An important component of the information retrieval capabilities Skeleton has inherited from INQUERY is a query formalism which permits the use of operators to express more precisely relationships among search query terms and how they contribute to the likelihood of a match between the search query and a given document.

The following query operators commonly occur in Skeleton development:

Sum Operator: #sum(T_1…T_n)
Query terms in the scope of a #sum operator are treated as having equal influence on the belief in a match between a query and a document.

Weighted Sum Operator: #wsum(W_s W_1T_1…W_nT_n)
Given the specified weight W_s, which declares the degree of belief in a match contributed by the #wsum expression, the weights $W_1 ... W_n$ specify the proportion to which the respective query terms $T_1 ... T_n$ in the scope of a #wsum operator contribute to that belief.

Ordered Distance Operator: #N(T_1…T_n)
All the query terms within the scope of an #N operator must be found within N words of each other in a document in order for the overall expression to contribute to a belief in a match.

And Operator: #and(T_1…T_n)
The more terms in the scope of an #and operator which are found in a document, the greater the belief in a match with the query.

Passage Operator: #passage$N$(T_1…T_n)
The more terms within the scope of a #passage$N$ operator which are found within a passage window of N words in a document, the greater the belief in a match between the query and the document.

Field Operator: #field(F R T_1…T_n)
The terms T_1…T_n contained in the scope of a #field operator are searched for in field F of documents in a given collection. An optional operator R may be specified to indicate a range of values to be searched for in F.

Search queries are generally submitted in plain text, in which case a default format is used to build a structured query which contains query terms identifed in the plain text input.

In Skeleton, the default format takes into consideration the fact that queries may be made against document representations containing OCR-generated text. In this format, which is illustrated in Figure 3, a #wsum operator is used to express a relationship between the relative importance of matching against the word tokens in a search query and matching against ngram character sub-sequences of them.

The first query term component of the #wsum expression is a #sum expression containing all the word tokens in the search query. This has the effect of treating all the word tokens as having equal influence on the matching of the query with a given document.

The second query term of the `#wsum` expression is another `#sum` expression whose constituents are `#passage5` expressions. Each of these `#passage5` expressions contains `ngram` sub-sequences for one of the word tokens in the plain text search query. It is important that the same method is used to determine the `ngram` samples for each search query token that is used to determine the `ngram` samples for word tokens in the document database.

The `#passage5` operator used in constituent expressions of the second query term provides a window of five word tokens to help catch OCR errors in which whitespace or other word token delimiters might have been introduced. A document which contains all the `ngram` sequences within the scope of a `#passage5` operator will receive a higher ranking than a document that contains only some of them. However, this operation does not over-penalize documents in which some of the search terms are not present; it merely ranks them lower in the list of retrieved documents.

3.3 Retrieval Performance

A series of experiments was run to determine the retrieval effectiveness of various `ngram` query formulations and database indexing methods. The measurement criterion was best improved performance using a given technique measured by the highest percent improvement in average precision over all recall levels when compared to baseline database and query formulations.

The experiments were performed using four different databases which were randomly degraded using Xerox OCR software error data developed by UNLV [3]. Higher word error rates were used to further degrade some of the randomly degraded databases. In such cases, the selected words were corrupted using typical character error substitutions. The actual word or character error rates achieved for the databases are unknown; the degree of degradation is measured only by how much worse retrieval performance is using standard queries on the degraded collections compared to performance on corresponding non-degraded collections.

A summary of the best retrieval performance results is given in Table 1. Collections with small document sizes are more negatively impacted than collections with larger average document lengths [2]. Thus collections with longer average sized documents have lower degradation levels for a given character or word error rate. Over all databases, the `#passage5` operator generally performed the best in binding `ngrams` together in the `ngram` component of a structured query, although not always significantly so. It was discovered that the `#and` operator was not sufficiently strong in joining `ngram` components, resulting in too many irrelevant documents being assigned high rankings. The `#0` operator, on the other hand, was observed to be too demanding in that any document missing one or more `ngrams` in its scope was assigned too low a retrieval ranking. The query formulations incorporating `ngrams` improved retrieval effectiveness over standard queries as database degradation increased, but the performance increases remained below retrieval effectiveness for non-degraded data.

Plain Text Query: *Mexican environmental newsletters*

Translated Query:
```
#wsum(10
      9 #sum(mexican environmental newsletters)
      5 #sum(#passage5(me mex mexi exica xic ican can an)
             #passage5( en env envi ironm onm ment tal al)
             #passage5( ne new news sl let tt ers rs)))
```

Figure 3: In structured queries formulated from plain text input, extracted word tokens in the first query term component of a `#wsum` expression are specified to contribute approximately twice as much to the belief of the `#wsum` expression as the `ngram` sequences of those tokens in the second component.

	CACM 6	NPL 6	TIME 7	WSJ89 6
Degradation	-26.6	-52.9	-10.9	-19.6
Docs	3204	11429	423	12380
Queries	50	93	83	49
Avg. Words/Doc	64	42	591	512
2-3 gram	#passage5 +8.4	#passage5 +36.0	#0 +3.9	#passage3/5 +4.5
2-5 gram	#passage5 +11.1	#passage5 +35.9	#passage5 +3.0	#passage3 +11.5
Restricted	#passage5 +14.7	#passage5 +38.8	#passage3 +3.8	#passage5 +11.9
Weighted	#passage5 +10.8	#passage5 +38.1	#and +5.1	#passage3 +11.7

Table 1: In this summary of retrieval performance experiments using assorted `ngram` query formulations, the reported values are percentage increases in average precision over all recall levels when the specified operators (`#passage5`, `#passage3`, `#0`, and `#and`) are used.

Indexing two, three, four and five-character `ngrams` generally outperformed query formulations using only two and three-character `ngrams`. Restricting the `ngrams` saved to the database to a subset of eight from the ordered sequence collected tended to improve performance, probably by reducing noise from extraneous `ngrams` and by improving overall term statistics used during query evaluation. However, the primary benefits of using a subset are a significant reduction in database size and improved evaluation speed.

An attempt was made to improve performance using a weighting of `ngram` components based on their positions in a word. Leading `ngrams` were assumed to be more important than middle `ngrams`, which were deemed more important than trailing `ngrams`. Each of the three ngram classes was down-weighted by roughly one half moving from leading to middle to trailing `ngram` samplings within a word. However such `ngram` weighting h ad no favorable impact on retrieval performance and only added complexity to query evaluation.

3.4 Future Indexing and Query Formulation Work

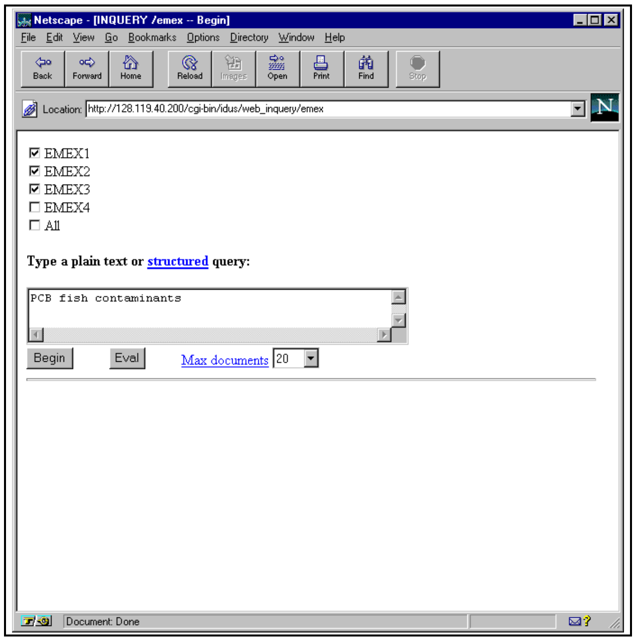
Future work on indexing OCR degraded texts and formulating queries using such databases will concentrate on reducing the size of the `ngram` database by being more selective in choosing which `ngrams` to index on. Furthermore, techniques will be developed to use `ngrams` for query term expansion rather than evaluating the `ngrams` themselves. A formulated query will then contain only matches and near matches of user query terms rather than `ngrams`, thus reducing query processing overhead. Query formulation may also include weightings based on the confidence measures for words produced by the OCR software itself. It is hoped that retrieval performance may continue to improve using such techniques. Finally, field based retrieval will be improved. The databases built for Skeleton processing already support fields, but the `ngram` query processor needs modification to maintain legal syntax in `ngram` binding operations when field based operators are present in the query.

4 Skeleton's Web-Based Interface

A Web-based interface was developed to demonstrate Skeleton's document image retrieval capabilities. A key component of the interface is a Java applet which supports the highlighting of query terms within GIF image representations.

An electronic form which permits the selection of one or more document collections and the submission of a search query is illustrated in Figure 4. (Document collections may be distributed across multiple machines running different operating systems.) After a plain text search query has been entered and the "Eval" button is pressed, a structured query is formulated and submitted to each each selected database.

Retrieval results from the selected databases are



Netscape - [INQUERY /emex -- Begin]

Location: http://128.119.40.200/cgi-bin/idus/web_inquery/emex

☑ EMEX1
☑ EMEX2
☑ EMEX3
☐ EMEX4
☐ All

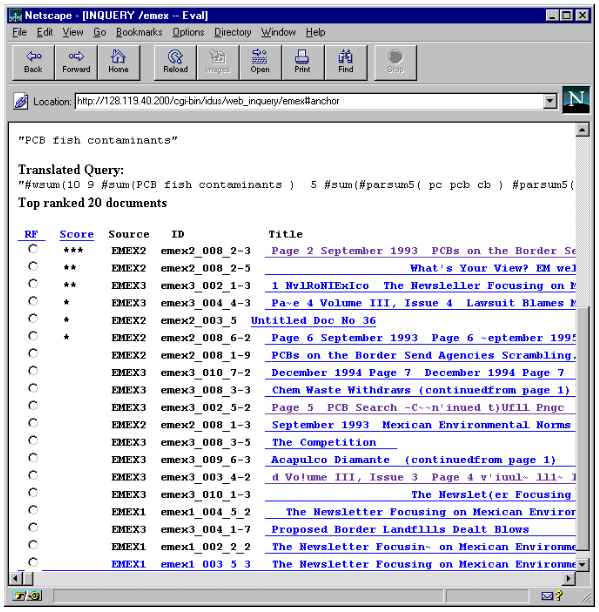
Type a plain text or structured query:

```
PCB fish contaminants
```

Max documents 20

Document: Done

Figure 4: Skeleton Search Query Form


Netscape - [INQUERY /emex -- Eval]
File Edit View Go Bookmarks Options Directory Window Help
Back Forward Home Reload Images Open Print Find Stop
Location: http://128.119.40.200/cgi-bin/idus/web_inquery/emex#anchor

"PCB fish contaminants"

Translated Query:
```
"#wsum(10 9 #sum(PCB fish contaminants )  5 #sum(#parsum5( pc pcb cb ) #parsum5(
```
Top ranked 20 documents

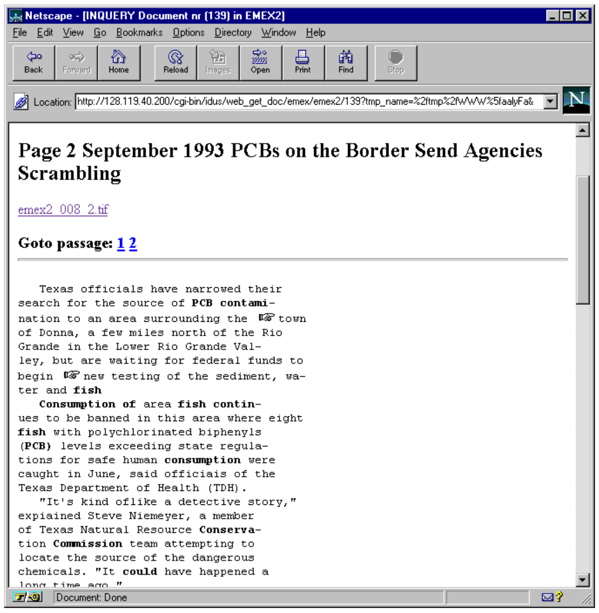
RF	Score	Source	ID	Title
○	***	EMEX2	emex2_008_2-3	Page 2 September 1993 PCBs on the Border Se
○	**	EMEX2	emex2_008_2-5	What's Your View? EM wel
○	**	EMEX3	emex3_002_1-3	1 NvlRoNIExIco The Newsleller Focusing on M
○	*	EMEX3	emex3_004_4-3	Pa~e 4 Volume III, Issue 4 Lawsuit Blames M
○	*	EMEX2	emex2_003_5	Untitled Doc No 36
○	*	EMEX2	emex2_008_6-2	Page 6 September 1993 Page 6 ~eptember 1995
○		EMEX2	emex2_008_1-9	PCBs on the Border Send Agencies Scrambling.
○		EMEX3	emex3_010_7-2	December 1994 Page 7 December 1994 Page 7
○		EMEX3	emex3_008_3-3	Chem Waste Withdraws (continuedfrom page 1)
○		EMEX3	emex3_002_5-2	Page 5 PCB Search -C~~n'inued t)Ufll Pngc
○		EMEX2	emex2_008_1-3	September 1993 Mexican Environmental Norms
○		EMEX3	emex3_008_3-5	The Competition
○		EMEX3	emex3_009_6-3	Acapulco Diamante (continuedfrom page 1)
○		EMEX3	emex3_003_4-2	d Vo!ume III, Issue 3 Page 4 v'iuul~ 111~ I
○		EMEX3	emex3_010_1-3	The Newslet(er Focusing
○		EMEX1	emex1_004_5_2	The Newsletter Focusing on Mexican Enviror
○		EMEX3	emex3_004_1-7	Proposed Border Landf1lls Dealt Blows
○		EMEX1	emex1_002_2_2	The Newsletter Focusin~ on Mexican Environme
○		EMEX1	emex1 003 5 3	The Newsletter Focusing on Mexican Environme

Figure 5: Skeleton Retrieval Results Form

merged and presented as a ranked list of titles, along with the structured query which was formulated from the plain text input. Figure 5 contains an example display of retrieved documents.

Titles of retrieved documents are linked to the OCR text output of their corresponding articles. Word tokens in the OCR text which correspond to word tokens or `ngrams` in the structured query are highlighted to faciliate understanding why the article was retrieved. Figure 7 contains an example display of the OCR text output of a retrieved article.

In a Web page display of the OCR text for a given article, a link is provided to a GIF image of the document page which contains the article. The GIF


Netscape - [INQUERY Document nr (139) in EMEX2]
File Edit View Go Bookmarks Options Directory Window Help
Back Forward Home Reload Images Open Print Find Stop
Location: http://128.119.40.200/cgi-bin/idus/web_get_doc/emex/emex2/139?tmp_name=%2ftmp%2fWWW%5faalyFa&
Document: Done

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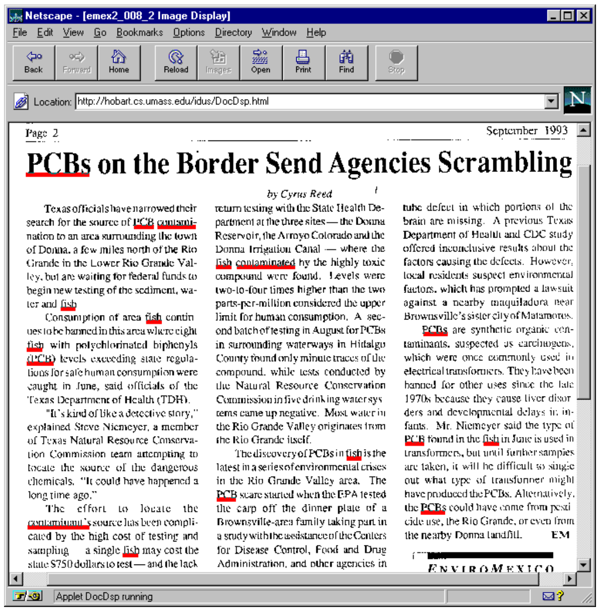
emex2_008_2.tif

Goto passage: 1 2

```
   Texas officials have narrowed their
search for the source of PCB contami-
nation to an area surrounding the ☞ town
of Donna, a few miles north of the Rio
Grande in the Lower Rio Grande Val-
ley, but are waiting for federal funds to
begin ☞ new testing of the sediment, wa-
ter and fish
   Consumption of area fish contin-
ues to be banned in this area where eight
fish with polychlorinated biphenyls
(PCB) levels exceeding state regula-
tions for safe human consumption were
caught in June, said officiais of the
Texas Department of Health (TDH).
   "It's kind oflike a detective story,"
expiained Steve Niemeyer, a member
of Texas Natural Resource Conserva-
tion Commission team attempting to
locate the source of the dangerous
chemicals. "It could have happened a
long time ago."
```

Figure 7: A display of OCR text for an article


Netscape - [emex2_008_2 Image Display]
File Edit View Go Bookmarks Options Directory Window Help
Back Forward Home Reload Images Open Print Find Stop
Location: http://hobart.cs.umass.edu/idus/DocDsp.html
Applet DocDsp running

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PCBs on the Border Send Agencies Scrambling

by Cyrus Reed

Texas officials have narrowed their search for the source of PCB contamination to an area surrounding the town of Donna, a few miles north of the Rio Grande in the Lower Rio Grande Valley, but are waiting for federal funds to begin new testing of the sediment, water and fish

Consumption of area fish continues to be banned in this area where eight fish with polychlorinated biphenyls (PCB) levels exceeding state regulations for safe human consumption were caught in June, said officials of the Texas Department of Health (TDH).

"It's kind of like a detective story," explained Steve Niemeyer, a member of Texas Natural Resource Conservation Commission team attempting to locate the source of the dangerous chemicals. "It could have happened a long time ago."

The effort to locate the contaminant's source has been complicated by the high cost of testing and sampling a single fish may cost the state $750 dollars to test — and the lack return testing with the State Health Department at the three sites — the Donna Reservoir, the Arroyo Colorado and the Donna Irrigation Canal — where the fish contaminated by the highly toxic compound were found. Levels were two-to-four times higher than the two parts-per-million considered the upper limit for human consumption. A second batch of testing in August for PCBs in surrounding waterways in Hidalgo County found only minute traces of the compound, while tests conducted by the Natural Resource Conservation Commission in five drinking water systems came up negative. Most water in the Rio Grande Valley originates from the Rio Grande itself.

The discovery of PCBs in fish is the latest in a series of environmental crises in the Rio Grande Valley area. The PCB scare started when the EPA tested the carp off the dinner plate of a Brownsville-area family taking part in a study with the assistance of the Centers for Disease Control, Food and Drug Administration, and other agencies in tube defect in which portions of the brain are missing. A previous Texas Department of Health and CDC study offered inconclusive results about the factors causing the defects. However, local residents suspect environmental factors, which has prompted a lawsuit against a nearby maquiladora near Brownsville's sister city of Matamoros.

PCBs are synthetic organic contaminants, suspected as carcinogens, which were once commonly used in electrical transformers. They have been banned for other uses since the late 1970s because they cause liver disorders and developmental delays in infants. Mr. Niemeyer said the type of PCB found in the fish in June is used in transformers, but until further sampies are taken, it will be difficult to single out what type of transformer might have produced the PCBs. Alternatively, the PCBs could have come from pesticide use, the Rio Grande, or even from the nearby Donna landfill. EM

ENVIROMEXICO

Figure 6: A display of a document page image containing an article

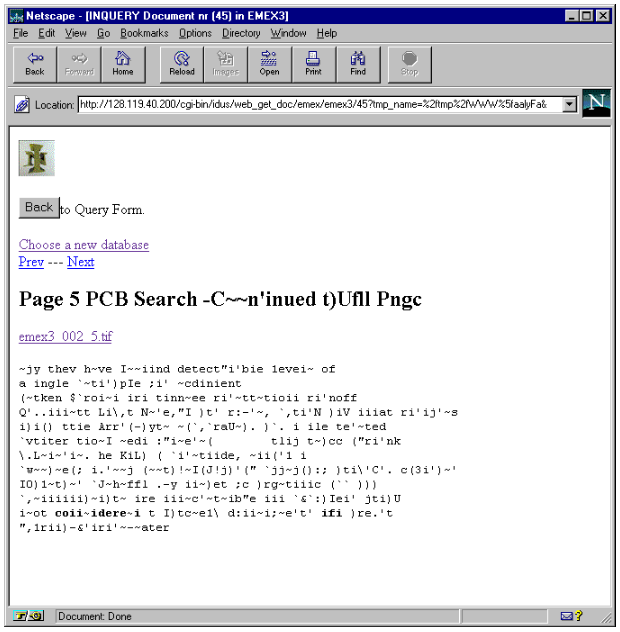
images used in the Web-based interface have been generated from the TIFF images used during image analysis. GIF images were needed in the current implementation of the interface because Java does not currently support TIFF image display.

Figure 6 contains an example display of a document image using the Java applet developed for the interface. Terms in the structured query are highlighted with red underlining to help focus attention on relevant parts of the page. Term highlighting is expanded somewhat in the image display with a rudimentary partial matching function which recognizes near matches of query terms through the use of a stemming routine. It is possible that a document image will be displayed without any terms highlighted if the query terms and their near matches are not actually found in the image. This may occur if the selected document was retrieved solely on the basis of `ngrams`.

Figure 9 contains a display of the text output for an article in which significant OCR errors occur. Despite the high error rate, a user may access the document image containing the article, illustrated in Figure 8, and determine that it is indeed relevant to the search query.

In future work on Skeleton's interface, evaluations of interface design will be made to determine how best to coordinate the display of OCR text output and document images. To further facilitate the search process, navigation buttons will be introduced into the image displays to make it possible to search through other page images of the same document.

If possible, the need to maintain GIF images of documents will be eliminated, but it may nevertheless be desirable to maintain higher resolution, color



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Page 5 PCB Search -C~~n'inued t)Ufll Pngc

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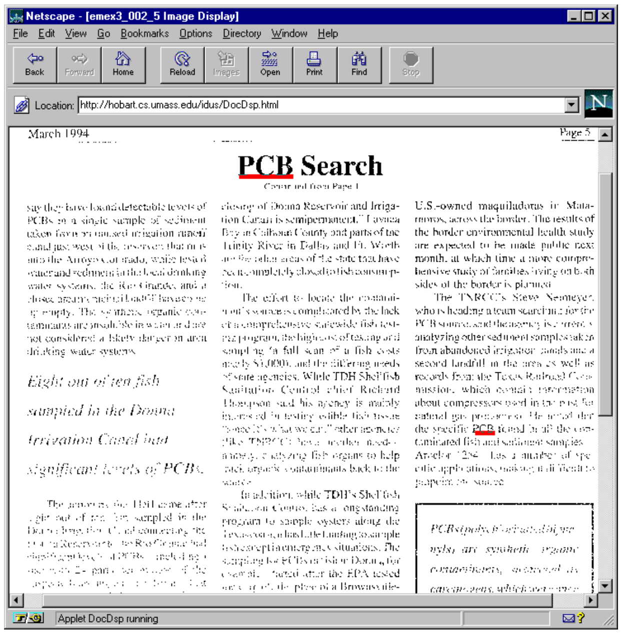
Figure 9: A display of an article's text containing significant OCR errors



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PCB Search

Continued from Page 1

say they have found detectable levels of PCBs in a single sample of sediment taken from an unused irrigation runoff canal just west of the reservoir that runs into the Arroyo Colorado, while tests of water and sediment in the local drinking water systems, the Rio Grande, and a closed area [illegible] have so far come up empty. The synthetic organic contaminants are insoluble in water and are not considered a likely danger in area drinking water systems.

Eight out of ten fish sampled in the Donna Irrigation Canal had significant levels of PCBs.

The [illegible] came after eight out of ten fish sampled in the Donna [illegible]

closing of Donna Reservoir and Irrigation Canal is semipermanent." Lavaca Bay in Calhoun County and parts of the Trinity River in Dallas and Ft. Worth are the other areas of the state that have been completely closed to fish consumption.

The effort to locate the contamination's source is complicated by the lack of a comprehensive statewide fish testing program, the high cost of testing and sampling (a full scan of a fish costs nearly $1,000), and the differing needs of state agencies. While TDH Shellfish Sanitation Control chief Richard Thompson said his agency is mainly interested in testing edible fish tissue ("since it's what we eat," other agencies like TNRCC [illegible] analyzing fish organs to help track organic contaminants back to the source.

In addition, while TDH's Shellfish Sanitation Control has a longstanding program to sample oysters along the Texas coast, it has little funding to sample fish except in emergency situations. The sampling for PCBs in fish in Donna, for example, started after the EPA tested [illegible] the plant of a Brownsville-

U.S.-owned maquiladoras in Matamoros, across the border. The results of the border environmental health study are expected to be made public next month, at which time a more comprehensive study of families living on both sides of the border is planned.

The TNRCC's Steve Neimeyer, who is heading a team searching for the PCB source, said the agency is currently analyzing other sediment samples taken from abandoned irrigation canals and a second landfill in the area as well as records from the Texas Railroad Commission, which contain information about compressors used in the past for natural gas production. He noted that the specific PCB found in all the contaminated fish and sediment samples, Aroclor 1254, has a number of specific applications, making it difficult to pinpoint the source.

PCBs (polychlorinated biphenyls) are synthetic organic contaminants, suspected as carcinogens, which [illegible]

Applet DocDsp running

Figure 8: A display of a document page image containing an article with significant OCR errors

images of documents for display to users. The attractiveness of this design feature is particularly compelling when viewing relatively poor quality images such as the one displayed in Figure 9.

7 Conclusions

The Skeleton architecture is based upon existing image analysis and document retrieval technologies. Incremental improvements in the technologies are being made in an effort to retain the scalability of the existing technologies while extending them to meet new challenges.

Acknowledgements

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