Development of a Multimedia Document Management System for Cooperative Work Environment

Sugao Sumiya* and Takashi Saito**

* Fuchu Works, TOSHIBA CORPORATION, Tokyo 183, Japan
** Engineering Department, Japan Airlines, Tokyo 144, Japan

Abstract

The recent rapid increase of the volume of documents in high tech industries has made the conventional method of authoring and managing documentation impractical. This situation necessitates the use of a technical document management system where cooperating groups create a large volume of documentation effectively.

This paper first discusses the means to implement a document database and the support functions for group works. Thereafter, the implementation of Jenesys is discussed. Jenesys (Japan Airlines Engineering NEtwork SYStem) is a technical document management and authoring system for aircraft maintenance information which consists of more than 100 types of documents. Jenesys is currently in operation.

1. Introduction

In high tech industries, the volume of documents which must be maintained to support their tasks is rapidly growing and will continue to grow.

The cause of this rapid increase of documentation is attributable to:

1. accumulation over time
2. technology advancement
3. creation of documents by re-using the existing documents
4. increasing number of related people

As the volume of documents increases, it is becoming almost impractical to create documents by typewriter (or hand) and paper, store them, retrieve them and use them because the required time and space increases.

On the other hand, the task of creating a document is a cooperative work of group members. The sharing of tasks for cooperative work takes the following forms:

1. Different persons are assigned to different documents or to chapters/sections (horizontal work sharing among human resources)
2. The document created by a person-in-charge is checked and authorized by other persons. (vertical work sharing among human resources)
3. Version management (work sharing along the time axis)

Documents in high tech industries are often high quality multimedia documents, which are not limited to simple textual information but often involve high definition graphics such as drawings. This is because the authors intend to transfer as much information as possible by a page.

For the above mentioned reasons, it has been deemed necessary to provide a technical document management and authoring system which is capable of handling high definition multimedia documents. It is important to provide a computer supported environment where creation and management of documents are done to yield more persuasive, higher impact, more precise and better looking documents in less time, and to store them systematically for later retrieval and reuse.

For the sake of the following discussion, this paper assumes that the term "large volume" documents indicates more than 10,000 documents or 100,000 pages.

Recently, research on the supporting functions for intelligent groups is becoming popular [KENN88]. At the same time, there are DTP (Desk Top Publishing) tools available for producing high quality documents.

In the recent years, it is becoming possible, due to the reduced price and increasing performance of EWS's (Engineering Work Station), to provide powerful personal computing power by assigning one EWS to each person. DTP, a powerful word processing tool, is taking advantage of this computing power. DTP software have more editing and layout functions, and finer print-
ing capabilities than word processing software, thus enabling electronic creation and storage of a wider range of documents which include fine quality drawings.

As powerful as it is, DTP is still a personal tool, and it is premature for it to be used by itself as a technical document management system for cooperative tasks. In other words, a simple DTP environment has the following problems.

1. Need for document database (DDB) to handle large volume documents
   - Although RDB (Relational Databases) is used for retrieval purposes by way of keywords, the data and the document pointed by it are not linked effectively. When the desired document name is found by searching the database, the user must note the document name, then issue an “open” command to the DTP software by giving the document name. It seems necessary to provide a database search tool which allows the user to directly open the document from within the search tool by constructing an effective DDB.
   - Documents are not journaled since they are outside the database scope even though RDB softwares often have journaling capability. The journaling capability of the documents must be provided along with that of the database.
   - The authoring environment does not provide capability to extract keywords from the documents into the database. The user must enter the same values twice (once in the document, once in the database). It does not allow extraction of keywords from the database into the document as well. These automatic extraction capabilities must be provided to reduce operational burden and to prevent inaccurate data transfer.
   - Among the large number of documents, those documents which are not active (by certain criteria) must be moved from the magnetic disks onto the optical disks, thus making room for newly created or revised active documents in the magnetic disks.

2. Lack of software functions to support cooperative tasks by work groups
   - Horizontal work sharing can be achieved by dividing a “paper” document into a smaller “electronic” documents. DDB can handle each electronic document by giving a unique name to it.
   - With the conventional environment, vertical work sharing is accomplished by routing the document via paper (after printing from DTP) and signing the printed document. In order to electronically handle the vertical work sharing, these functions (i.e. routing and approving) must be done within the scope of the technical document management system.
   - Version control must provide security for the authenticated documents (once approved, nobody can change that version of the document). For modification of documents, the function is provided to check out a copy of the latest document from the DDB in case a revision is desired by a user. The document must be modified, then routed, approved, and eventually checked into the DDB.

Section 2 discusses the method to implement the DDB and the functions to support cooperative tasks by work groups. Section 3 discusses the actual implementation of Jenesys system. Section 4 provides the conclusion.

2. Document Database and the Supporting Functions for Cooperative Tasks

This section focuses on the following subjects which are required of a technical document management system in a cooperative task sharing environment;

1. Structure of the DDB and its relationship with the DTP.
2. The DDB and the supporting functions of group works

2.1 Document Database (DDB)

There has been various research on databases which handle multimedia documents including the studies such as object oriented approach [SCHR84, DAAR86, MASU87].

Recently, this is discussed in conjunction with group works [IREN87].

Further, the international standards for document exchange between information systems are defined [ISO88].

When documents are filed such as "paper" documents, there usually is a two dimensional table as a notebook of document index or a PC database which holds a certain data for each document.

This implies that a two dimensional table is good for storing keywords for each document. Even when the number of documents is large, use of RDB (Relational Database) will be sufficient for managing the document data.

Although RDB is a traditional style of database structures, it has been successful in business applications. RDB should be used as the core of the DDB which handles multimedia documents, by taking advan-
It is very important for the design of the DDB that the documents stored are approved official documents. Since, by definition, official documents will not be modified once they are approved, they can be treated as primitives (unbreakable entities). Therefore, document data can be considered as a variable length field (document field) in the DDB. (Figure 1)

![Document Database](image)

**Figure 1** Document Database

Based on these discussions, we adopted a method (RDB+Pointer method) to store a pointer in the DDB which points to the document data (Figure 2).

![Document Index and Document Data](image)

**Figure 2** Document Index and Document Data

Our DTP software runs on the EWS which has fairly big computing power. EWS's pass data from the document being processed onto the server computer. This scheme allows the server computer to concentrate on the management of the DDB and the data from the EWS, providing load and risk sharing between computers. Even when the server computer becomes off line, the users are still able to continue creating or revising a document if it has been previously transferred to the workstation.

RDB+Pointer method is a powerful, though very orthodox, solution based on the assumption that "approved documents cannot be modified." By adopting this method as the basic concept of the DDB, we constructed a technical document management system, the discussion of which follows, where a very large document database is a part.

### 2.2 Retrieval

Document index can be retrieved as RDB. Next, we discuss the opening (displaying) of documents via DDB.

In the following discussions, "document field" is a field which points to the binary data holding document information which can be "openable" by DTP software. Since document field cannot be a keyword field, DDB search is done by use of other fields.

Other fields can be displayed immediately since the field lengths are short (1000 characters at most), however, document field is different. It is reasonably acceptable to display the document itself only upon operator demand basis since document data may be mega bytes in some cases.

Therefore, how should we present the situation where there are multiple candidates to display? The fact that there are multiple candidates indicates that one could not identify a single document from the key fields only. This is inevitable because the information contained in the document itself is much larger than that in the key fields.

Because of this, we need to pay special attention to the design of the human interface. One should be able to pick a candidate, display the document, read it, and if the document was not the one wanted, then pick a different candidate without going back to the retrieval process again.

### 2.3 Multi-User Transaction

It should be assumed that database transactions such as updates, inserts, deletes and selects occur concurrently from multi-users. Since off-the-shelf RDB's are already capable of handling the multi-user transactions, we only need to assure multi-user transactions for the document field.

Document data pointed by the document field often exceeds one mega byte, sometimes reaching 10 mega bytes. This indicates that the processing time to support transactions is long, requiring close attention in implementing the transaction processing functions.

### 2.4 Journaling and Recovery

In order to prepare for the remote chance of database
corruption, transactions such as insertions, updates, deletions need to be journaled.

The scheme mentioned in section 2.1 that one document data is a primitive, leads to the possibility of journaling and recovering its insertions, updates and deletions like other RDB fields.

As in the case of section 2.3, large sizes of document data needs special attention.

2.5 Keywords in Document

Usually, a user writes keywords in the document when one creates/revises the document. It is inefficient to write the same keywords in the DDB.

In order to make both authoring and management of documents efficient, it is important to avoid entering the same data twice. When, for example, a user has to enter the title of a document into the document itself and into the title field of the database, we consider that the database and the document is inefficiently linked. We do NOT call this type of database a DDB.

DTP software is the major human interface for the technical document management system, thus we must minimize the interaction between a user and non-DTP software.

In the "paper" world, we usually use pre-printed forms with pre-determined areas where certain data values are to be entered to make the documents look consistent even though the documents are written by different persons. The use of the pre-determined forms allows us to know where to extract values for automatic entry into the corresponding database fields. When an "electronic" form is prepared, we build "document fields" in areas from which the values are to be extracted.

"Electronic" blank forms have the following structure;
(1) Fixed area : Text or graphics which a user is not allowed to change.
(2) Document field : The value here is extracted to the corresponding database field, or the value in the corresponding database field is automatically entered here.
(3) Free area : User can freely write any text or graphics here.

The following two major functions enables us to link database and documents;
(1) FFI (Forms Fill in) : The values entered into "fields" in the document are extracted and put into appropriate database fields when it is checked in.
(2) RFFI (Reverse FFI) : Data in the database is extracted to be put into the document when the document is checked out.

Figure 3 shows the data flow of the FFI function. Figure 4 shows the data flow of the RFFI function. Figure 5 is an example of blank forms.

2.6 Data Volume of Documents and DDB

DTP is required to make the data compact and DDB is required to effectively store them in magnetic disks.

In order to make room for newer data in the magnetic disks, inactive document data in the magnetic disks need to be moved to optical disks. In this section, we...
discuss the storage management. A criteria is set up for moving documents from the magnetic disks to the optical disks. A criteria is specified for each document type by use of the following conditions;

(1) Access frequency: If the document is not accessed for a set period, the document is moved to an optical disk.

(2) Age: If the document’s age limit (time since creation) is expired, the document is moved to an optical disk.

For the compaction of the document data, it is especially important to compress image data. Four mega bytes are required to represent a black and white A3 image at 400 dpi. Large DDB system needs to rapidly compress the image data in the workstation to reduce the storage space and communication load, and to rapidly decompress it in the workstation to display on the screen.

### 2.7 Hierarchical Human Organization and Group Works

In engineering industries, human organization is set up before initiating group works. This is to share tasks among groups and define each task’s person-in-charge and its approval path. Thereafter, each group’s and each person’s job description are defined.

The same is true in document authoring. A person-in-charge is assigned to a document or to a chapter (subchapter) of a document. The person-in-charge researches related documents, makes contact with the related people, and creates or revises the document in his/her responsibility. The authorizer checks the document and approves it when he/she is satisfied with it.

The important points in the flow of the group works are thus;

(1) Records of the documents which the person-in-charge referenced

(2) Document mail function between person-in-charge and authorizer etc., and annotation capability to send a short message along with the document

(3) Audit trail such as the person-in-charge and authorizer, creation date, authorization date etc.

### 2.8 Document Mail and Approval in Support of Group Works

Tree structure such as cabinet-drawer-folder is suitable for personal data environment. Since a user seldom possesses more than 100 personal files, the size of personal files is small enough for eyeball searching using the tree structure file system.

For documents checked out from the DDB, it is necessary to include an in-basket in the personal local file system. Checked out documents will be put into an electronic folder, and then sent to the user’s in-basket. The recipient of the document moves it from the in-basket to his/her personal work area, where the document is filled in, and/or modified. The author puts the pre-registered signature. The document is then sent to the next person’s in-basket.

Most blank forms have frames in which a person can put his/her signature in. When a signature is placed in one of these frames by "SIGN" function, creation date and author’s name need to be automatically entered in the database as well. When the final authorization is given to the document, the authorization date and the name of the authorizer also need to be automatically entered into the database.

There may be other signatures between the author’s signature and the final authorizer’s signature. These signatures will not cause the database entry. In other words, only the author’s and the final authorizer’s names and dates need be entered into the database, since we think that only these signatures and dates are important for administrative purposes.

As for the "SEND" function, the system must provide means to annotate the document by posting a note in the vicinity of the text/graphics in question. The system must also provide functions such as sending the document back to the originator for corrections, and labeling documents for "RUSH" handling by the recipient. The system must retain reasonable flexibility as in the current pencil-and-paper environment.

Figure 6 shows the personal environment and the document flow.

![Figure 6: Personal Data Environment and Document Data Flow](image)
2.9 Electronic Approval and Security

In the "pencil-and-paper" environment, approvals are manifested by signing on the sheet of paper, or especially in Japan, by placing the person's authentic stamp or a date stamp. Even though the documents are being treated by electronic means, the same "traditional" visible effect must be preserved.

It is necessary to resolve the following counterfeit concerns in order to gain support for electronic approvals;

(1) Since electronic signatures (or stamps) are implemented as bitmap images, they can be easily copied electronically to different documents with no degradation of image quality.

(2) A printed-out document can be re-read by scanner to copy the signature.

Even if there is a signature on the face of a document, it should be considered a counterfeit if there is no entry of authorizer and authorization date in the database. Therefore, the system must be implemented such that, when a print out is requested for a particular document, it is printed properly only if it is the authentic document (the one with authorizer and authorization date in the database). In order to discourage attempts to falsify the signature by re-reading via scanner, a countermeasure is required to degrade the visible quality of the signature by taking advantage of the characteristics of the scanner.

2.10 Version Management

The difficulty of the version management depends on the complexity of the document system [WONK88]. The version management requirements for this DDB application are relatively simple since the documents to be checked in had been approved, and will not be modified.

Version management functions are realized by check-out and check-in functions. The system shall inhibit modifications after check-in. Modification and creation of a document will only be possible through a check-out function.

For a book where various person-in-charges are assigned to divided chapters/subchapters, the revision timings and the number of revisions are different for each division of the book. In addition to the revisions of chapters/subchapters, there are revisions as a book which occur asynchronously with the chapter/subchapter revisions. The version management must take these two levels of revisions into consideration.

3. Implementation of Jenesys

Jenesys (Japan Airlines Engineering NEtwork SYstem) is an implementation based on the previous discussions.

3.1 General Description of Jenesys

One of the responsibilities of the Engineering Department of Japan Airlines is to issue documents which are required for aircraft maintenance. The company owns Boeing 747's, 747-400's, 767's and Douglas DC-10's, a total of 100 aircrafts. Each type of aircraft requires about 500,000 pages of documents. There are 3,000,000 pages of aircraft maintenance information in the department.

Jenesys hosts about 100 types of documents, among which 40 types are accompanied with electronically stored documents.

Documents are classified as follows.

(1) Manuals: Broken down to chapters. Each chapter has fixed person-in-charge. Aircraft manufacturers provide revisions by magnetic tapes. Approval is required.

(2) Modification Instructions: Reuse of other documents is frequent. Approval is required.

(3) Evaluation: Evaluation of information from outside the company. Determines actions required and sets forth an implementation schedule. Approval is required.

(4) Report and Letter: Issued by Engineering Department. Approval is required.

(5) General Document/Memo: Approval is not required.

Jenesys's hardware structure consists of a super mini-computer (TOSHIBA DS6060) as the department server, eight EWS's (TOSHIBA AS3260HM, enhanced version of Sun 3/260) as printer/scanner/group local servers, 46 EWS's (TOSHIBA AS3150M, enhanced version of Sun 3/150) as personal workstations. The 54 EWS's are connected to one of four LAN (Local Area Network) 's out of the super mini computer.

DTP software used by Jenesys is off-the-shelf TOSHIBA AS-Documents package which is capable of interprocess communications, thus enabling application software to manipulate documents through AS-Documents. AS-Documents consists of the following subsystems.

(1) DocMaker: Document authoring, editing (Enhanced version of FrameMaker, capable of Japanese/English multi-language processing)

(2) DocImage: Entry and editing of image data
Figure 7 describes Jenesys's functions and their interrelationship. Description of the functions follow.

1. **Document Database**: Consists of database and the stored documents. Disk is dual. Documents are version controlled. Old documents are moved to a jukebox type optical disk subsystem.

2. **Blank Forms**: Each document type has its own blank form(s). Blank forms are stored in the department server.

3. **Journal**: Documents which are checked in are stored in an optical disk system by time sequence, and by document types. This results in storing the same document in four different places, assuring the safety of the data.

4. **Receiving**: Documents are delivered to the Engineering Department either by paper or by electronic media (magnetic tapes).

   - **Paper**: Data received by paper is captured into Jenesys by scanning. A few document types require typing the content on the paper into the system.

   - **Electronic Media**: Data is captured by magnetic tapes. The content of the tapes is converted to Jenesys format via a filter program. (Boeing issues 30,000 manual pages per aircraft type at four months period.)

5. **Retrieval**: Searches the document database and shows the match list. User may choose "OPEN" function to display the selected document. The document cannot be altered from this function. Alteration must be through "CREATE DOCUMENT" or "REVISE DOCUMENT" functions.

6. **Create Document**: Jenesys asks the user the type of the document and other information. Jenesys assigns a new document number, enters it into the database, writes the number in the blank form, then checks out the blank form. The user fills in the blank form using the DTP software, then puts the signature on it using the "SIGN" function of Jenesys.

7. **Revise Document**: Jenesys asks the user the type of document and document number. Jenesys copies the document with the newest revision number, increments the revision number, and checks out the copy. The user modifies it using the DTP software, then puts the signature on it using the "SIGN" function of Jenesys.

8. **Document Mail**: When the entry is complete, one sends the document to the next person. When a person has a comment, one can send it back to the originator with the comment. The person can also display the documents which the originator referenced when he/she created the document. When he/she is satisfied with the document, he/she either puts the signature on it and sends it to the next person, or gives the final approval.

9. **Document Check-In**: After final approval, documents are checked in. This process is automatic unless the office standard procedures require otherwise.

10. **Temporary Issue**: Documents requiring expedited delivery are identified by the entry into the "Temporary Issue" field in the documents. The "Temporary Issue" documents are automatically routed to the distribution section. "Temporary Issue" program prints out the document and the coversheet for expedited handling without waiting for periodic issue cycle, which may be two weeks to three months depending on document types.

11. **Periodic Issue**: Documents are assembled in a form of a book at predetermined intervals, and
3.2 Implementation of Jenesys

Jenesys started operation in April, 1990, and is gradually increasing the number of document types in operation. The system is functioning as planned to create DTP quality documents as cooperative efforts of group members and of work groups by sharing a large number of documents.

Document index and document data, which constitute DDB, both reside in the department server, which is a super mini-computer.

RDB (ORACLE) is used for implementing document index in order to store various document attributes.

Document data is stored in the document index as a pathname and a file name. Document data is a UNIX file.

Document data is represented by DTP (AS-Documents) data format which includes text data, image data and simple vector data.

Figure 8 shows the relationship of these elements.

DocDBM has sub-processes which respond to the requests from EWS's. A sub-process handles each request given to DocDBM. By this method, the system tries to reduce the overall degradation of services when time consuming concurrent processes are requested from multiple users.

Journaling of the document data is performed by DocDBM. Journaling of RDB is provided by an ORACLE function.

Alteration of DDB schema shall be avoided. However, it is very difficult to decide individual schemata for 100 document types. We provide standard set of 160 fields and 30 spare fields. This simplifies the task of adding a new document types.

The function to display the document is realized by including a software button on the DocDMT dialog box. The user is to pick a document from the list, then press "OPEN" button on the DocDMT dialog box. Refer to Figure 9. If the user is not satisfied with the displayed document, he/she can pick another candidate from the list and "OPEN" it.

In order to perform FFI and RFFI between the DDB and DTP, blank forms are prepared for all the document types. The author fills in the form. In addition to the document fields, there are free text entry area. Human interface is carefully designed such that users can use the same interface when they are entering text either into a field or into free text area.

Inactive documents in the magnetic disks are moved into the juke-box type optical disk system using predetermined rules (life cycle control rules).

All EWS's have IPA (Image Processing Accelerator) board installed, which is capable of image compression/decompression using MMR format, in order to rapidly process image data. IPA board processes CCITT test chart (400 dpi) at 0.4 second/page and compresses if down to 1/50 of it's original volume.

Jenesys handles five document categories. Looking from the horizontal work sharing point of view, a manual as a book is written by multiple people. For
others, there is a single author for each document.

Manuals are divided into chapter-subchapter-sections, to each of which a person in charge is assigned. The entity which corresponds to a chapter-subchapter-section division is called a title block. This title block constitutes a document in Jenesys and is handled as other documents are.

ex. 747AMM34-00-01 Title Block
EI-JEZ/G-18 Document

Recently, there is various research on document processing systems which support hot links to paragraphs, words, graphics in different documents [SPEC88]. Jenesys provides two kinds of links even though the basic concept is RDB+Document data.

(1) Link to reference document: Jenesys remembers the documents which are referenced in the process of creating a document. These reference documents can be called up when required.

(2) Link to paragraph number: JAL customized maintenance manual and Boeing's original maintenance manual have identical paragraph numbers. By using the paragraph number, the same paragraph in the Boeing and JAL maintenance manuals can be displayed side by side for ease of comparison.

Though the probability of requiring the links to the other documents are not high since the contents of the other documents are physically duplicated into the current document, certain types of links are necessary as mentioned above.

In order to show that the document is authentic, Jenesys provides "OFFICIAL PRINT" function which uses the "TOSHIBA Method." (Figure 10) The "TOSHIBA Method" checks the database for approval first. If the document has been approved, then it prints the approval signature with a background shade. The background shade is carefully selected so that the appearance of the shade degrades when re-read by scanner due to the resolution of the scanner, thus discouraging primitive counterfeit efforts.

3.3 Example of Operation

The following is a description of sample document flow, FFI, RFFI, document mail functions of Jenesys.

The document type in this example is AMM400 (Maintenance Manual for Boeing 747-400). An AMM revision is always accompanied by a routing slip (RS) since one cannot sign on the face of an AMM page. (Refer to Figure 5)

(1) Check out a new AMM400 title block Blank forms of AMM400 and RS, in the department server, are sent to the user's in-basket. In the document database, a new record is inserted with some fields filled. RFFI is performed at this time to write RS number, document type, etc. in the RS form automatically. Figure 11 (a) is the confirmation dialog box which appears when checking out a new document.

(2) Figure 11 (b) shows the screen where blank forms of AMM400 and RS are opened.

(3) The user enters the information into the forms. Figure 11 (c) shows the screen after he/she signed the RS.

(4) The user sends the document to his/her supervisor. Figure 11 (d) shows the "SEND" dialog box.

(5) Figure 11 (e) shows the authorizer's screen where he/she is about to approve the document.

(6) Figure 11 (f) is the check-in dialog box. AMM400 TB and RS are checked into the database in the department server. The check-in program performs FFI to extract certain data from RS into the database.

4. Summary

We discussed a technical document management system where a large volume of documents are maintained by cooperative efforts of work groups using DTP software.

The major characteristics of Jenesys is the "database of documents", integration of "DTP software to create high quality documents" and "document creation/revision by cooperative efforts of work groups." RDB+Pointer method is a powerful, though very
orthodox, solution based on the assumption that "approved documents cannot be modified" without creating a new record for the revision. By adopting this method as the basic structure of the DDB, we designed this technical document management system.

One of our future challenges is to provide an external interface of DDB so that Jenesys can capture documents from and send documents to remote sites. It is desired to make available the standard interface for exchange of high quality DTP documents and the associated database elements and link information.

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REFERENCES

[IREN87] Irene Greif, Sunil Sarin, Data Sharing in Group Work, ACM Transactions on Office Information System, April 1987, pp. 187 - 211.