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Managing construction drawing documents with an automatic index system

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ABSTRACT

The effective management of construction drawings is an important provision in the design and construction process, particularly where they amount to many hundreds or thousands. Whilst nowadays the majority of drawings are CAD based and therefore compatible for computer based management systems, there is still little evidence of this being employed. This fact is surprising in view of the substantial benefits that have been proved through the employment of the system described.

1. INTRODUCTION

Construction documents are traditionally prepared by manually composing a drawing and its labelled details on the same or separate sheets of paper. Normally, the number of drawings may amount to hundreds or thousands, when a design project is either at a large scale or features very sophisticated contents. The relationship between a drawing and related details may cross many sheets. The cross-referencing of design information becomes very complicated to manage [1].

The indexed relationship between a drawing and its details is often changed in response to modifications of drawing locations, design contents, or index numbers. Not only are index numbers usually miss-referred, but some of the required corrections can also be easily neglected [2]. Typically, experienced senior architects are given the time-consuming task of reviewing check-sets to ensure accuracy [3-4]. Neglected design conflicts raise the potential of construction errors on site. Error-prone and effort-consuming situations leave the manual indexing method inefficient and ineffective.

This paper provides an automatic index system for managing construction drawing documents on computers. The system consists of four modules: labelling system, grid-indexing system, index-referring system, and library-retrieving system. These modules issue and update indexes automatically to improve drawing accuracy. They also facilitate yet reduce man-hours required for architecture and construction drawing management.

2. MAPPING RELATIONSHIPS

This research is related to index system's correlating drawing, sheets of paper, and details. Therefore, the definition of corresponding terms needs to be clarified. Sheets refers to the paper containing project information like drawings or details. An architectural design project is normally represented as a set, or sets, of drawings which is separated into a number of sheets that include plans, elevations, sections, etc. A detail is a specific type of drawing containing graphic and non-graphic information which can be repeatedly used in many drawings. Sheets, drawings, and details can be presented by the feature diagram placed on the left in Figure 1. Drawings are presented in lighter shade in contrast to details in darker shade. Drawings and details use two-headed arrows to indicate cross-referencing among sheets.

Each two-headed arrow in Figure 1 symbolises a basic unit in constructing references. The unit, as a basic relationship, is established by relatively positioned and indexed contents such as a drawing, a label (a circle with a horizontal line), or a detail (see the right part of Figure 1). The label's position within a drawing must be fixed to indicate where a detail occurs. Label contents are the indexes indicating where a referred detail is located in a set of construction drawings. The index contains a detail and sheet number. The relationship between drawings and details is very complicated. Relational hierarchies along with their associated revisions generate this condition.

2.1. Relational hierarchy

Sheets, drawings, and labels are hierarchically constructed (see Figure 2). The hierarchical relationship is presented as tree structures in two groups using two-headed arrows as references [5]. The left group is composed of sheets, drawings, and labels from top to bottom. In contrast, the right group only includes sheets and details. Sheets are sequentially numbered, and each one contains a different drawing number that is alphabetically categorised. Each drawing contains various numbers of labels that are named according to the right group of the two tree structures. A sheet, which contains drawings and details, would appear in both groups.

2.2. Relation types

The hierarchical relationships may be classified into three mapping types: labels, drawings, and sheets in relation to details.

1) Label-detail mapping: This mapping type categorises the relationship between labels with identical contents and a specific detail. Since one detail can be referred by more than one label, the relationship can be either one-to-one or many-to-one.
2) Drawing-detail mapping: A drawing may have more than one type of detail specified, and each type may appear more than once. The mapping of label numbers in a drawing to detail types projects one-to-one, many-to-one, or many-to-many relationships (see Figure 3).
3) Sheet-detail mapping: The mapping in terms of drawing numbers on a sheet to detail types could be one-to-one, one-to-many, many-to-one, or many-to-many relationships. This mapping type includes all relationships shown in Figure 3.

2.3. Relationship update

Indexed relationships are updated into four types, as shown in Figure 4, depending on the modified sequence, the number of labels, and existing details. The first type has both a label

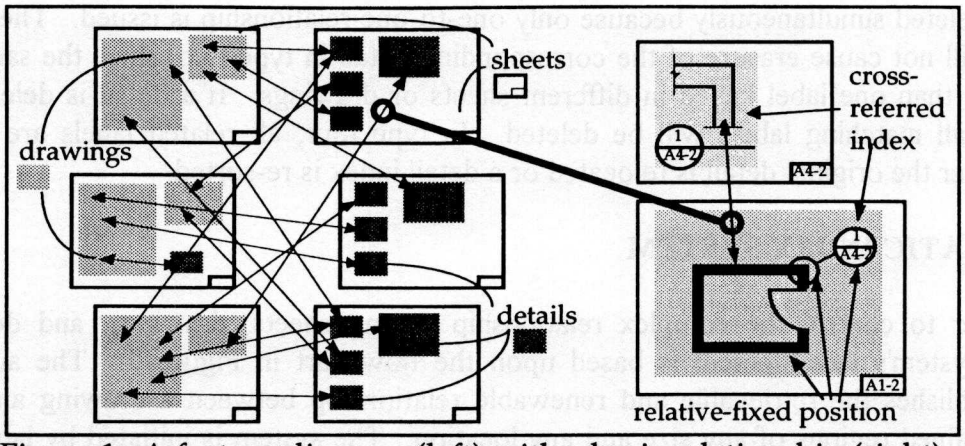

Figure 1. A feature diagram (left) with a basic relationship (right)

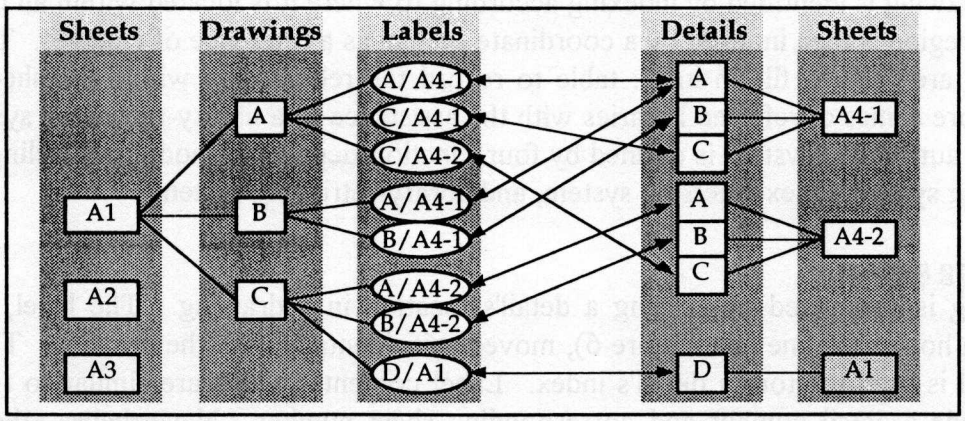

Figure 2. Relational hierarchy

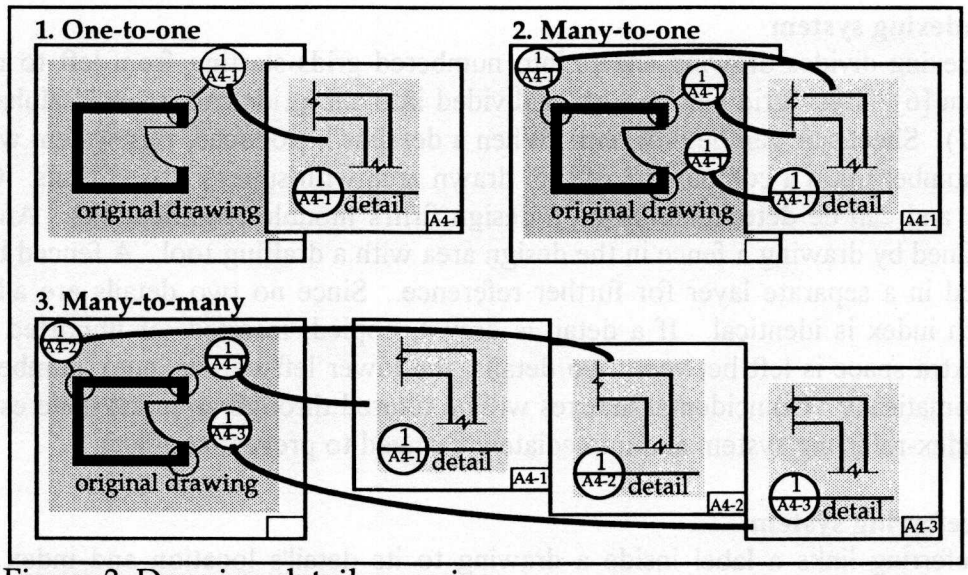

Figure 3. Drawing-detail mapping

and detail deleted simultaneously because only one-to-one relationship is issued. The deletion of a label will not cause erasure of the corresponding detail in type two, since the same detail serves more than one label keyed in different sheets or drawings. If a detail is deleted as in type three, all matching labels will be deleted. In type four, all related labels are changed because either the original detail is relocated or a detail index is re-sorted.

3. AUTOMATIC INDEX SYSTEM

In order to control the complex relationship among sheets, drawings, and details, an automatic system's development is based upon the flowchart in Figure 5. The auto-index system establishes the retrievable and renewable relationship between a drawing and details based on defined regions of any size and any location. The system is initiated by labeling the focus area within a drawing to indicate where a detail is located. The location of a detail and its source drawing is identified by indexing according to where it is located within an individual sheet. The region is then indexed by a coordinate system as a reference of changes. The labels and indexes are used to fill an index table to record the relationship within the sheets. The table can store names of referred libraries with the assistance of a library-retrieving system. As a result, the auto-index system is defined by four function-dependent modules: labeling system, grid-indexing system, index-referring system, and library-retrieving system.

3.1. Labeling system

Labeling is conducted by circling a detail's location in a drawing. The label, which is divided by a horizontal line (see Figure 6), moves coincidentally with the drawing. The circle-shaped label is used to store a detail's index. Label contents, which are similar to traditional usage, include a detail number and corresponding sheet number. Nevertheless, the content would not be issued until the following systems are executed.

3.2. Grid-indexing system

Grid-indexing divides drawing sheets into numbered grids starting from left to right and top to bottom [6]. Each grid can be further divided into sub-grids and indexed alphabetically (see Figure 7). Sheet size can be different. When a detail is introduced, this system will assign it an index number upon a comparison of the drawn area with superimposed grids. Grid size is adjustable and can be determined upon a design firm's module specifications. An indexed region is defined by drawing a fence in the design area with a drafting tool. A fenced boundary can be stored in a separate layer for further reference. Since no two details are allowed to overlap, each index is identical. If a detail is drawn, copied, inserted, or imported between grids or if extra space is left between two details, the lower left corner index number will be selected automatically. Coincidental indexes will be filtered through an index table established within the index-referring system and immediately changed to prevent conflicts.

3.3. Index-referring system

Index-referring links a label inside a drawing to its detail's location and index number. Detail related information is initiated whenever a detail is created. Label information is initiated by inheriting information from the corresponding detail selected from a pop-up menu. The system updates all influenced indexes whenever a detail is drawn or relocated. If a detail is deleted, all labels in different drawings will be automatically removed. The index table of

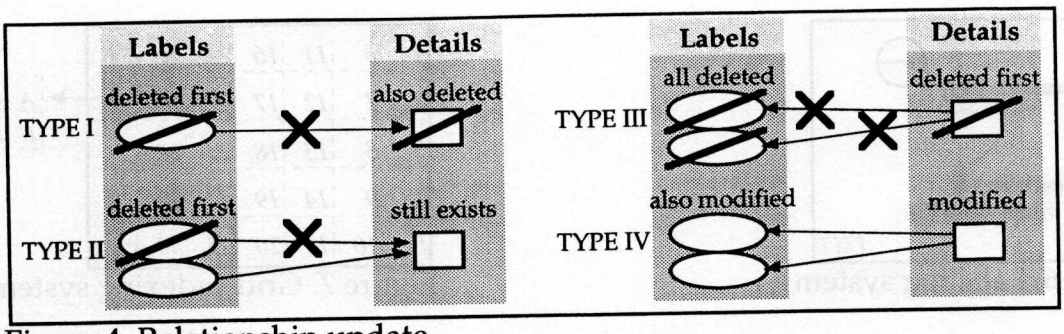

Figure 4. Relationship update

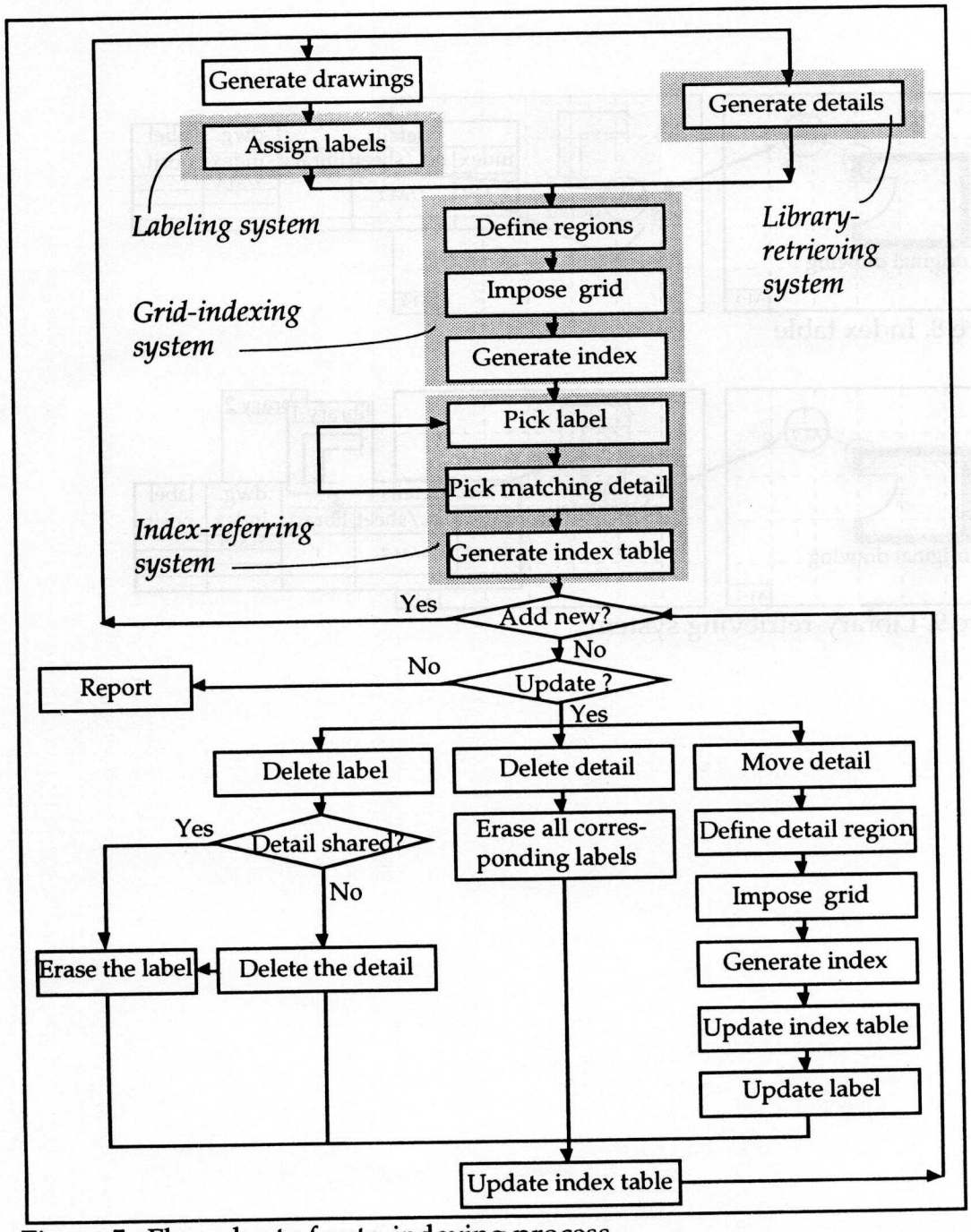

Figure 5. Flow chart of auto-indexing process

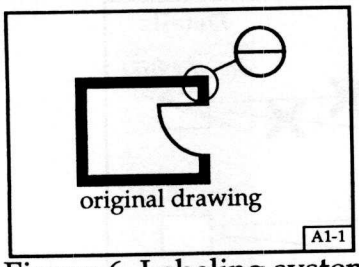

Figure 6. Labeling system

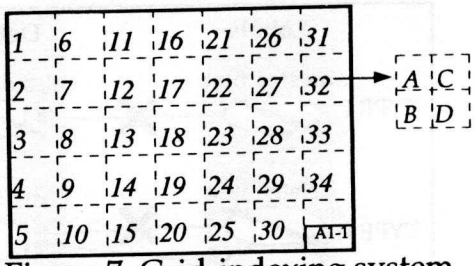

Figure 7. Grid-indexing system

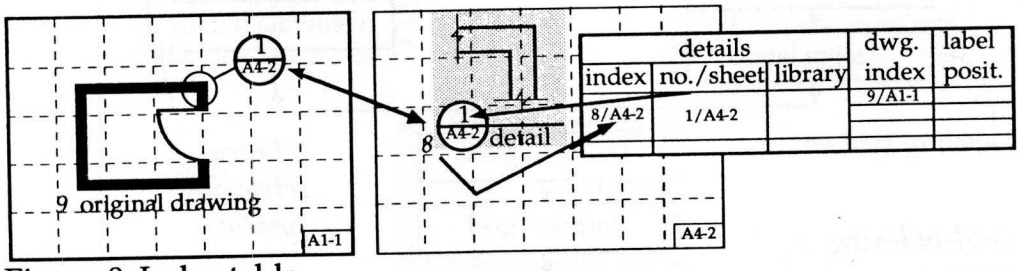

Figure 8. Index table

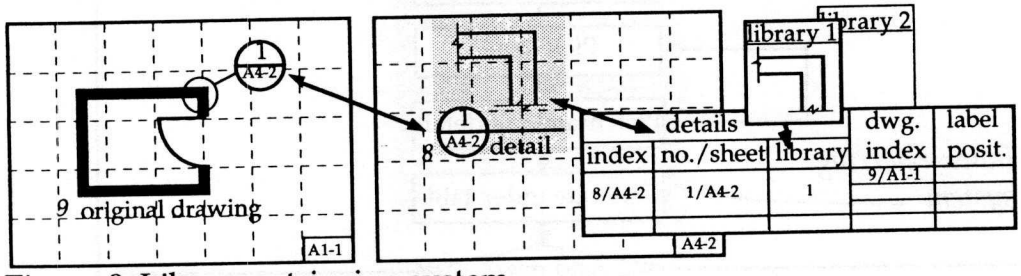

Figure 9. Library-retrieving system

each sheet can be merged into a final report under the direction of a design team leader for monitoring.

An index table includes information related to details, labels, drawings, and sheets. Detail-related information consists of index content, detail number, sheet number, source library name, and an array of referred labels. Drawing-related information is the index indicates location on a sheet. Label-related information includes drawing location, detail contents, and sheet number (see Figure 8).

3.4. Library-retrieving system

Library-retrieving increases drafting efficiency when detail libraries are provided: details are retrieved by directly linking labels to the database through an index table [7] (see Figure 9). Along with eliminating drafting, copying, or pasting frequency, drafting file size is also reduced.

4. ADVANTAGES

Advantages of applying auto-indexing are listed as follows.

1) Generate indexes automatically:
   Indexes, labels, and index tables are automatically generated.
2) Updates index automatically:
   All referring labels are automatically removed whenever a detail is deleted. Indexes of all referring labels are simultaneously updated whenever a detail is relocated, as are label contents.
3) Improves drawing accuracy:
   The auto-index system virtually eliminates manual indexing and numbering; consequently, drawing accuracy in terms of cross-referencing among sheets is maintained even if frequent changes are involved.
4) Facilitates drawing management process:
   Index tables, created by index-referring system, record all information regarding detail's indexes, locations, source drawings, referred libraries, etc. The tables facilitate the drawing management process with detailed information.
5) Reduces man-power:
   A traditional check-set process, which heavily relies on experienced professionals, can be simplified by the auto-indexing system. Thus, the simplified checking process helps reduce traditional man-power needs. In addition, with the assistance of a library-retrieving system, man-power can be reduced even more.

5. CONCLUSION

The auto-index system is suitable to manage large amounts of drawing information. With the assistance of the four modules, the relationship occurring between drawings and details is clarified and automatically updated. As a result, drawing management becomes efficient, and man-power is reduced. Leaving more time for other tasks.

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