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Lo et al.

(54) SELECTIVE PREVIEW AND PROOFING OF DOCUMENTS OR LAYOUTS CONTAINING VARIABLE DATA

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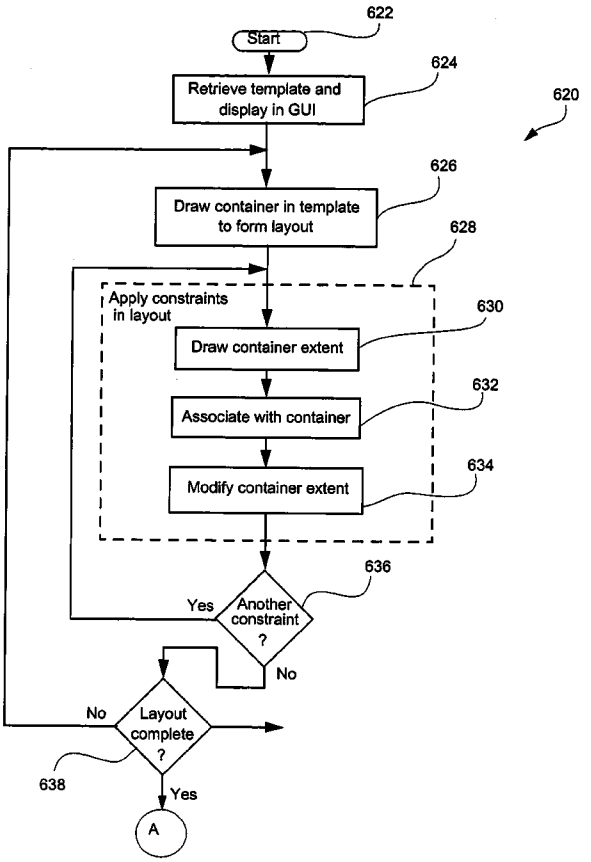
(57) **ABSTRACT**

Methods and apparatus for proofing **(644)** a variable document intended for printing are disclosed in which a GUI **(2000)** is configured to allow user manipulation of layout rules associated with content containers within a template for variable document generation. Selective proofing **(2100)** involves proofing a plurality of variable data documents each formed from a common layout in which variable data content is placed into containers having locations and sizes within the layout and defined by layout rules. Measures of variation **(2103, 2106)** and measures of deviation **(2109, 2110)** are calculated. The measures of deviation are processed **(2112)** to give a deviation value. Once completed for each document, the deviation values of the documents are compared **(2114)** to identify at least one group of the documents for presentation for further assessment. Live proofing includes creating a layout **(2002)** for a variable data document based upon a template established in the GUI. A container **(2010)** is set in the template to form the layout, which is then modified to thereby generate an exemplary document by placing exemplary content into the container, wherein a dimension of the container and/or a position of the container are varied based upon a property of the placed content. The exemplary document is displayed in the layout via the GUI to enable visual proofing by the user.



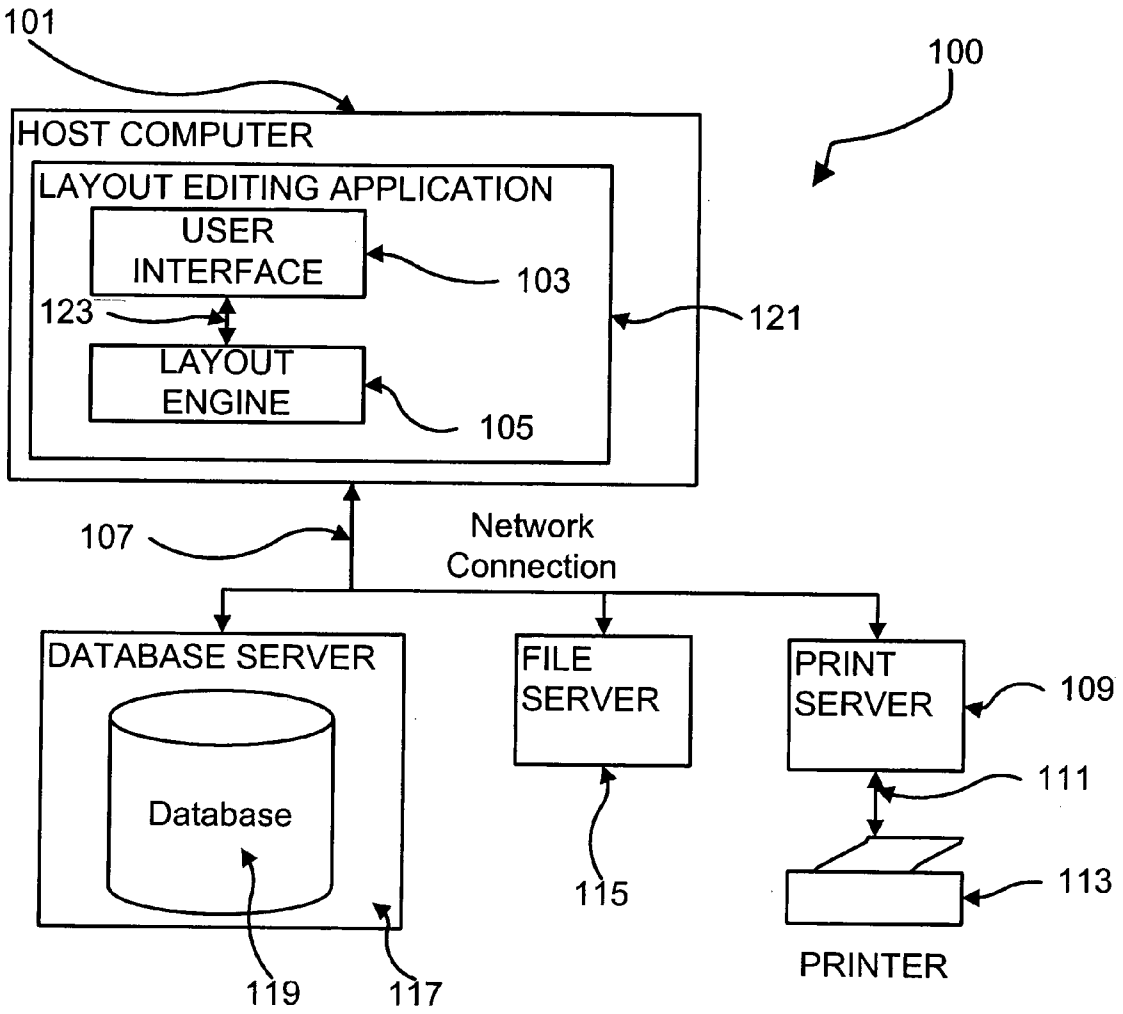

101
100
HOST COMPUTER
LAYOUT EDITING APPLICATION
USER INTERFACE
103
123
121
LAYOUT ENGINE
105
107
Network Connection
DATABASE SERVER
Database
FILE SERVER
PRINT SERVER
109
111
113
115
PRINTER
119
117

Fig. 1A

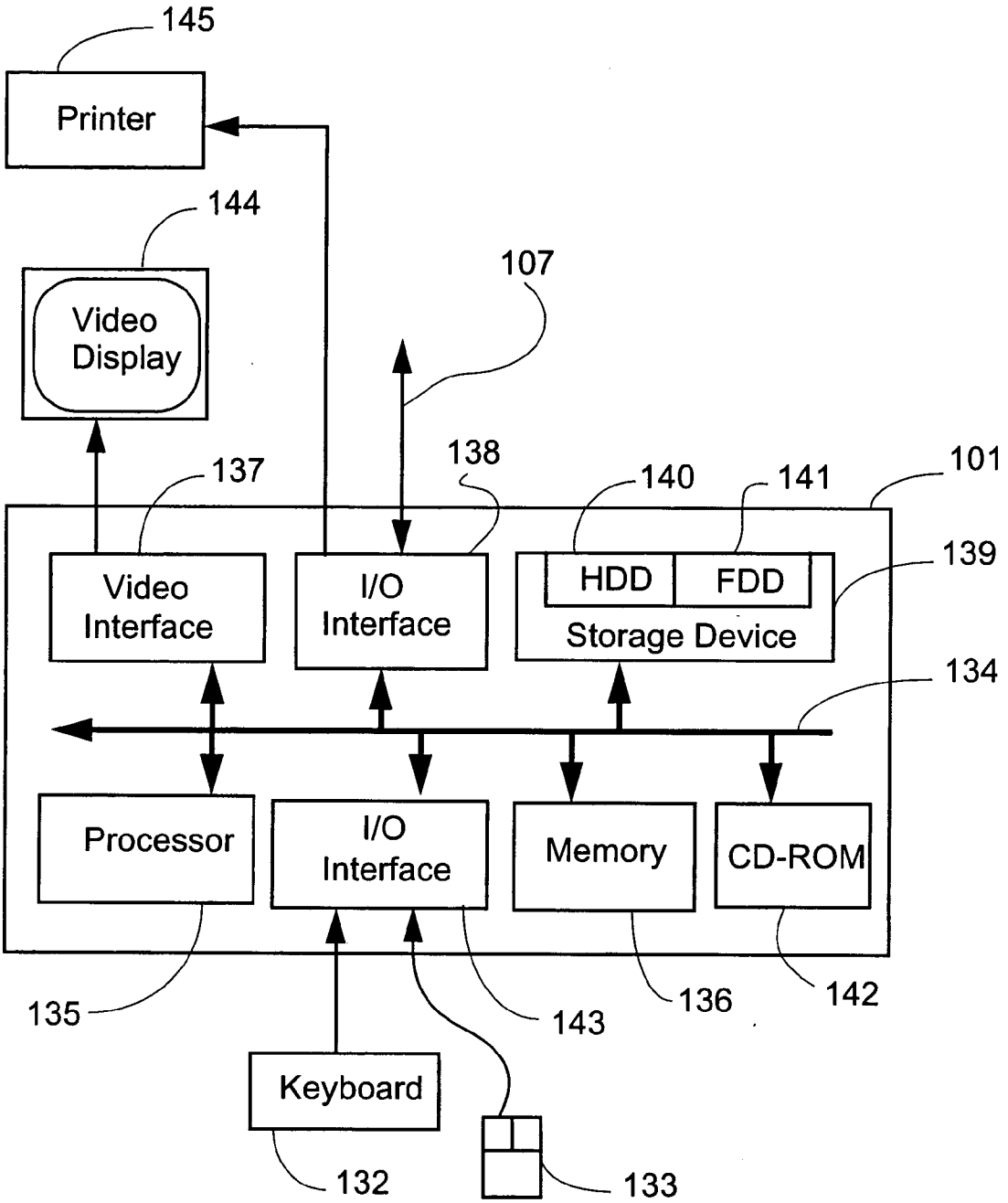

145
Printer
144
Video Display
107
137
138
140
141
101
Video Interface
I/O Interface
HDD
FDD
Storage Device
139
134
Processor
I/O Interface
Memory
CD-ROM
135
143
136
142
Keyboard
132
133

Fig. 1B

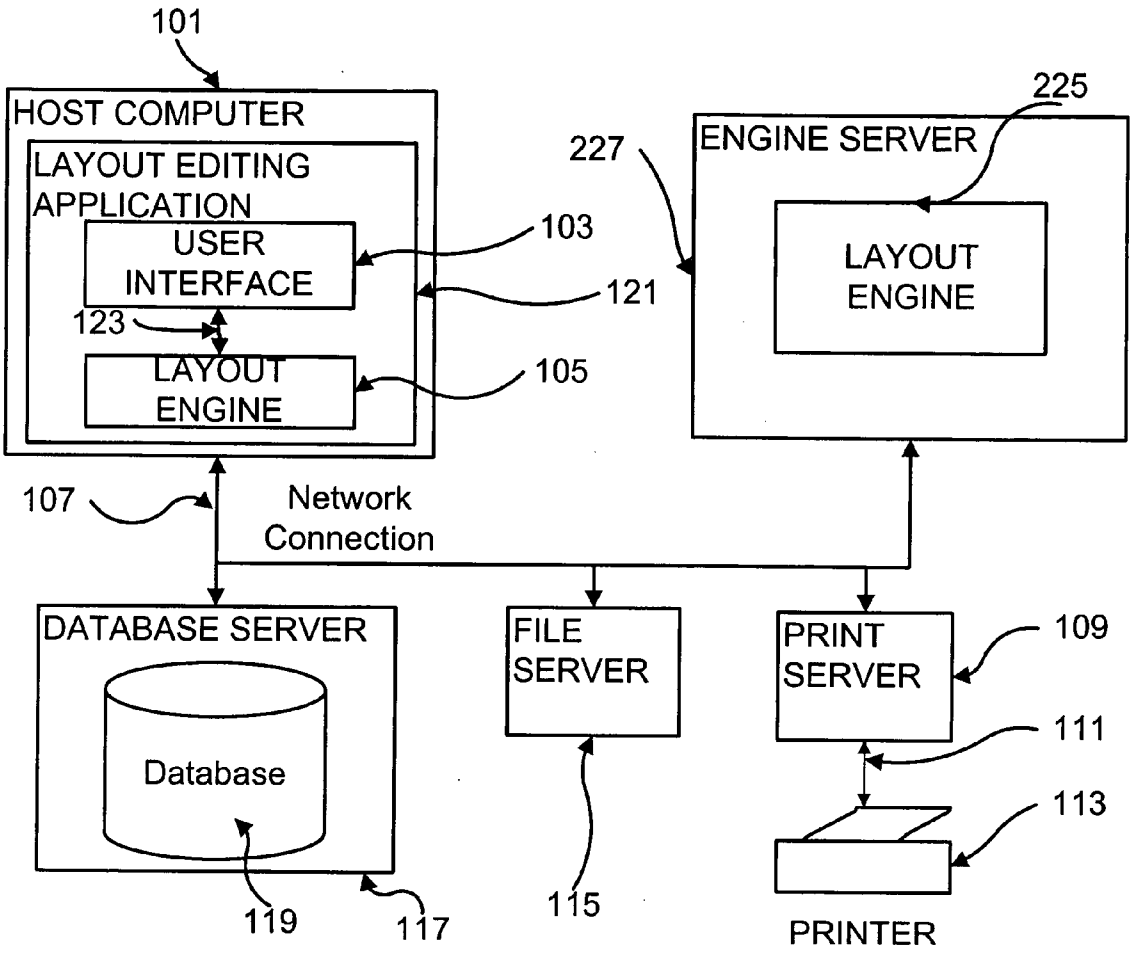

101
HOST COMPUTER
LAYOUT EDITING APPLICATION
USER INTERFACE
LAYOUT ENGINE
103
121
123
105
227
225
ENGINE SERVER
LAYOUT ENGINE
107
Network Connection
DATABASE SERVER
Database
FILE SERVER
PRINT SERVER
109
111
113
PRINTER
119
117
115

Fig. 2

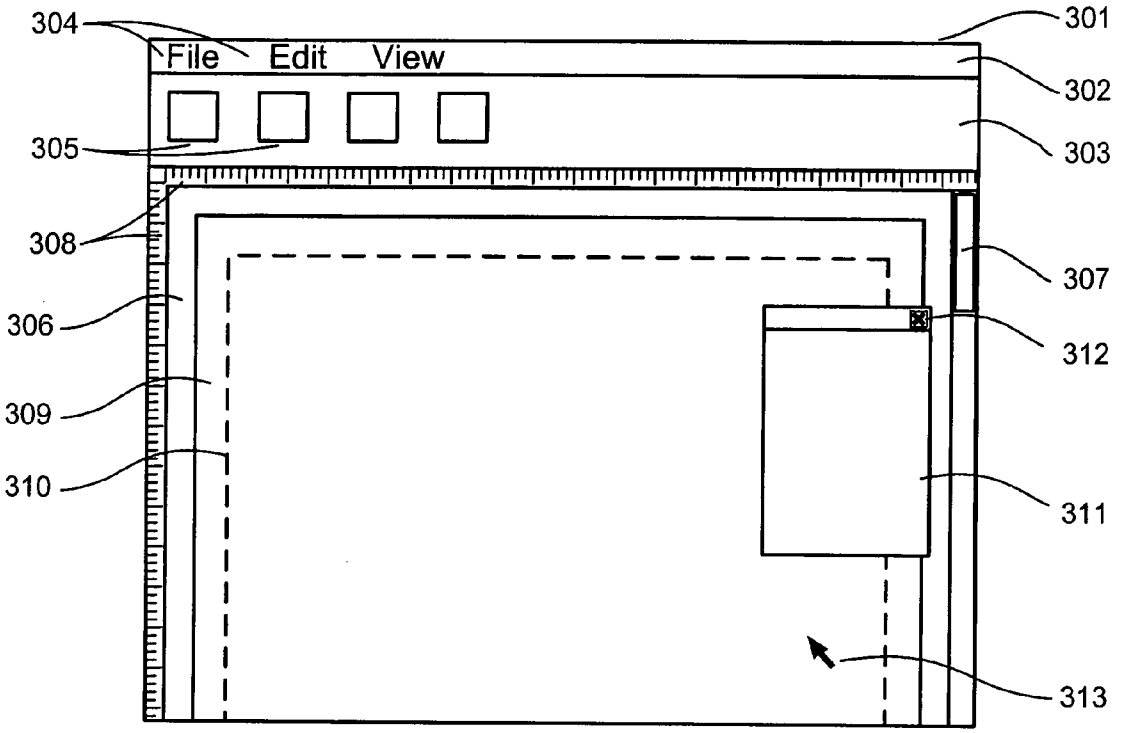

304
File
Edit
View
301
302
303
305
308
307
306
312
309
310
311
313

Fig. 3

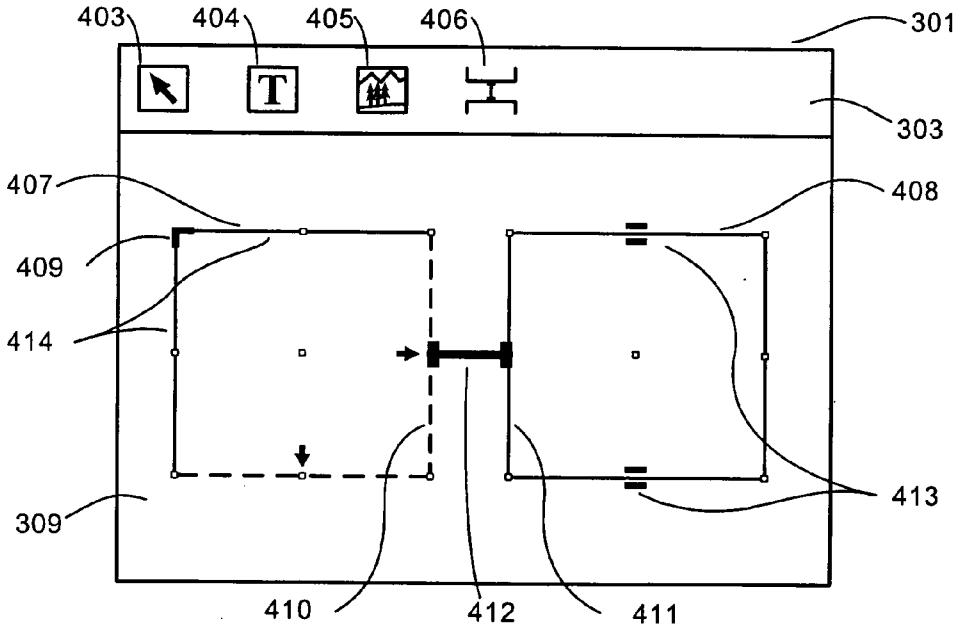

403
404
405
406
301
T
303
407
408
409
414
413
309
410
412
411

Fig. 4

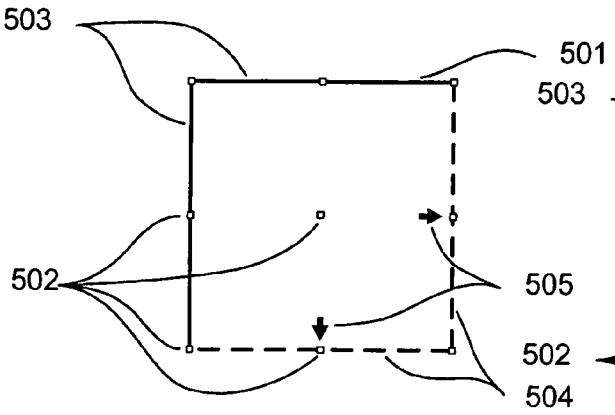


Fig. 5A

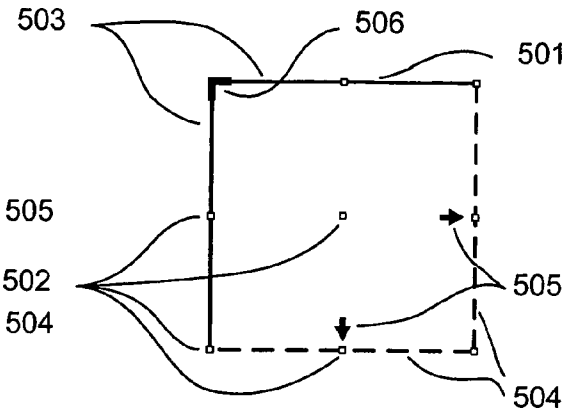


Fig. 5B

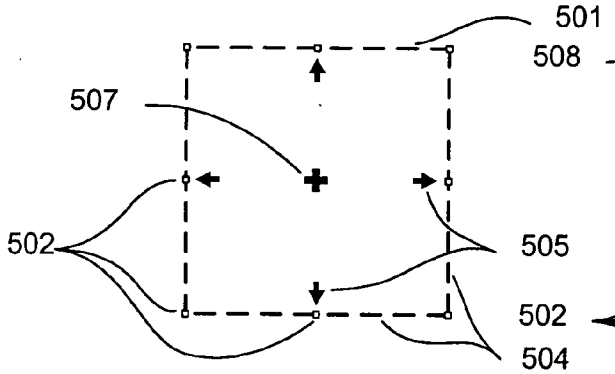


Fig. 5C

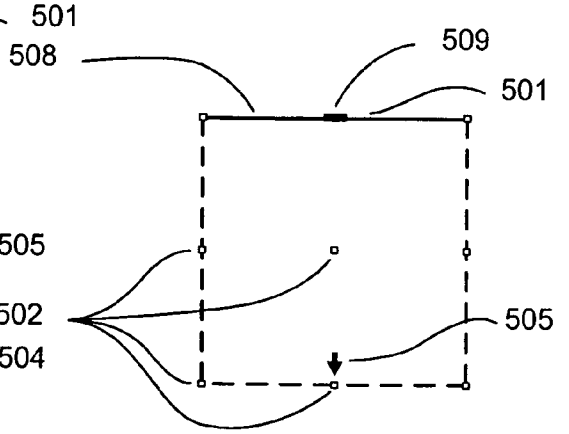


Fig. 5D

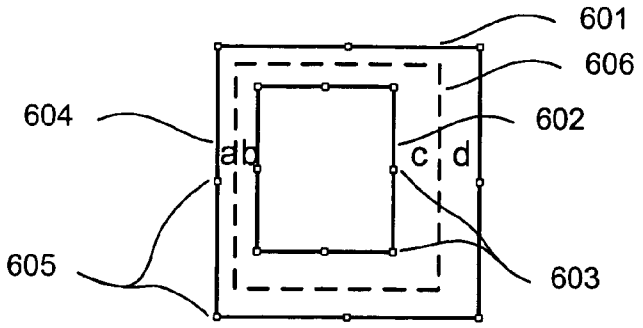


Fig. 6A

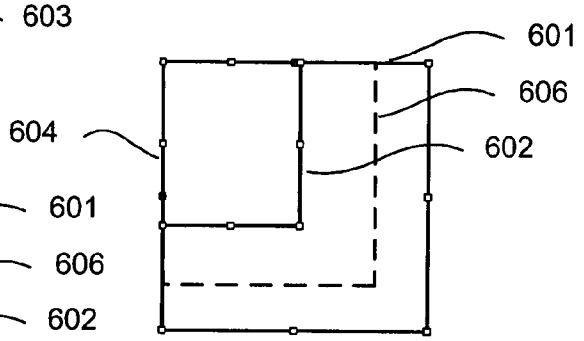


Fig. 6B

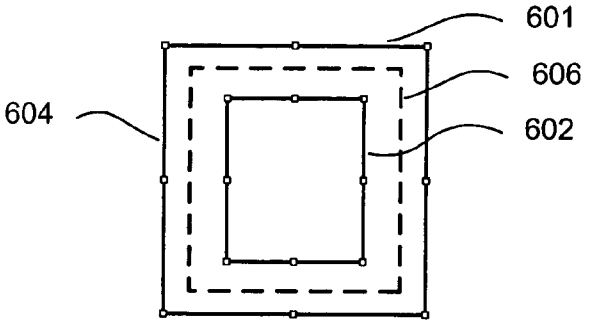


Fig. 6C

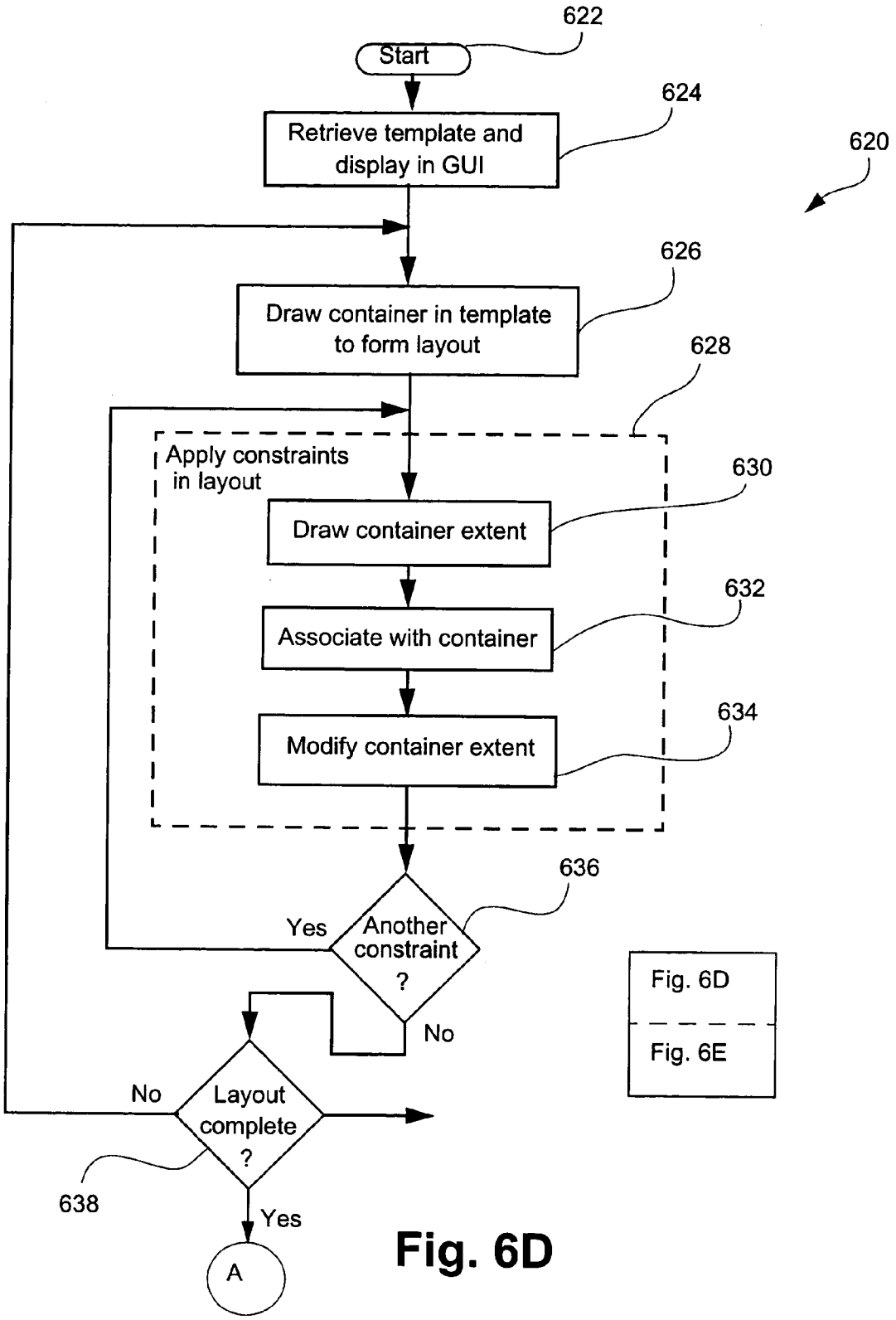

622
Start
624
Retrieve template and display in GUI
620
626
Draw container in template to form layout
628
Apply constraints in layout
630
Draw container extent
632
Associate with container
634
Modify container extent
636
Yes
Another constraint ?
No
Fig. 6D
Fig. 6E
No
Layout complete ?
638
Yes
A

Fig. 6D

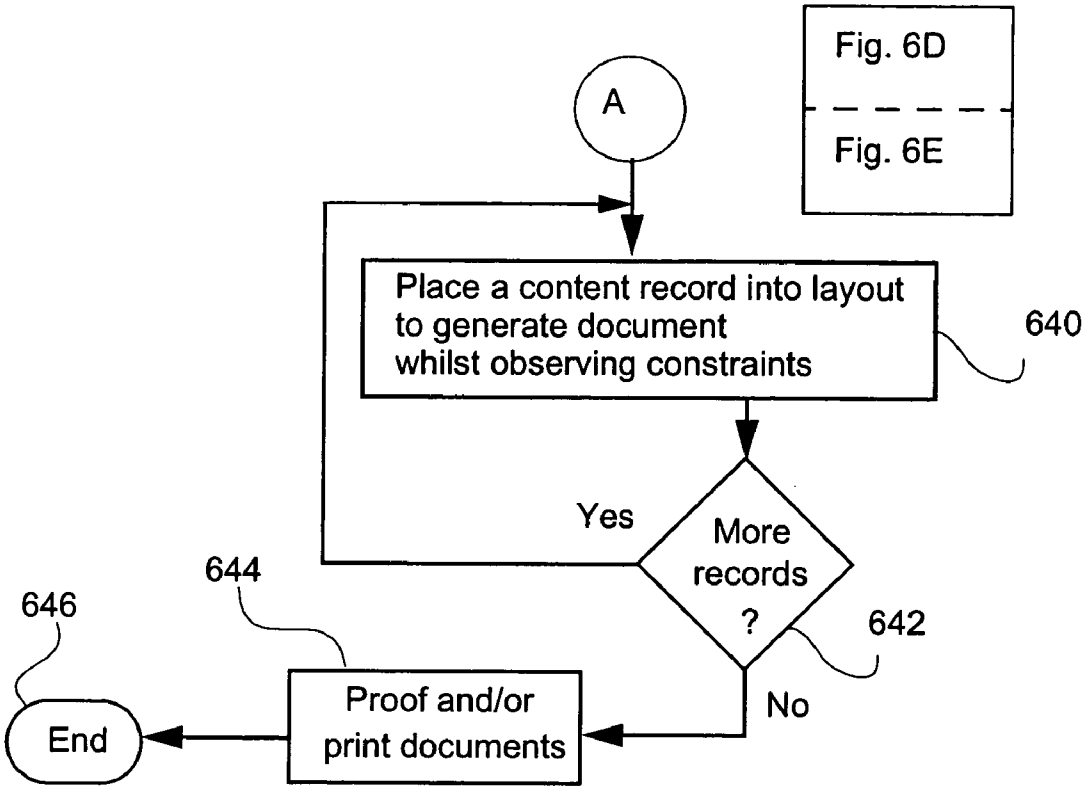


Fig. 6D
Fig. 6E
A
Place a content record into layout to generate document whilst observing constraints
640
Yes
More records ?
642
No
644
Proof and/or print documents
646
End

Fig. 6E

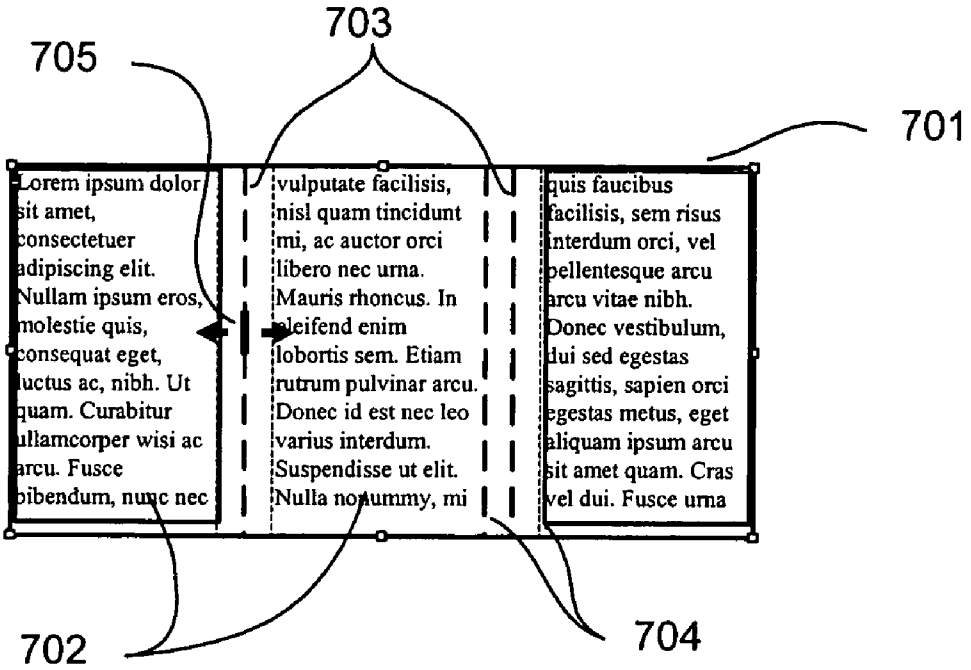

703
705
701
Lorem ipsum dolor
sit amet,
consectetuer
adipiscing elit.
Nullam ipsum eros,
molestie quis,
consequat eget,
luctus ac, nibh. Ut
quam. Curabitur
ullamcorper wisi ac
arcu. Fusce
vulputate facilisis,
nisl quam tincidunt
mi, ac auctor orci
libero nec urna.
Mauris rhoncus. In
eleifend enim
lobortis sem. Etiam
rutrum pulvinar arcu.
Donec id est nec leo
varius interdum.
Suspendisse ut elit.
Nulla nonummy, mi
quis faucibus
facilisis, sem risus
interdum orci, vel
pellentesque arcu
arcu vitae nibh.
Donec vestibulum,
dui sed egestas
sagittis, sapien orci
egestas metus, eget
aliquam ipsum arcu
sit amet quam. Cras
vel dui. Fusce urna
702
704

Fig. 7A

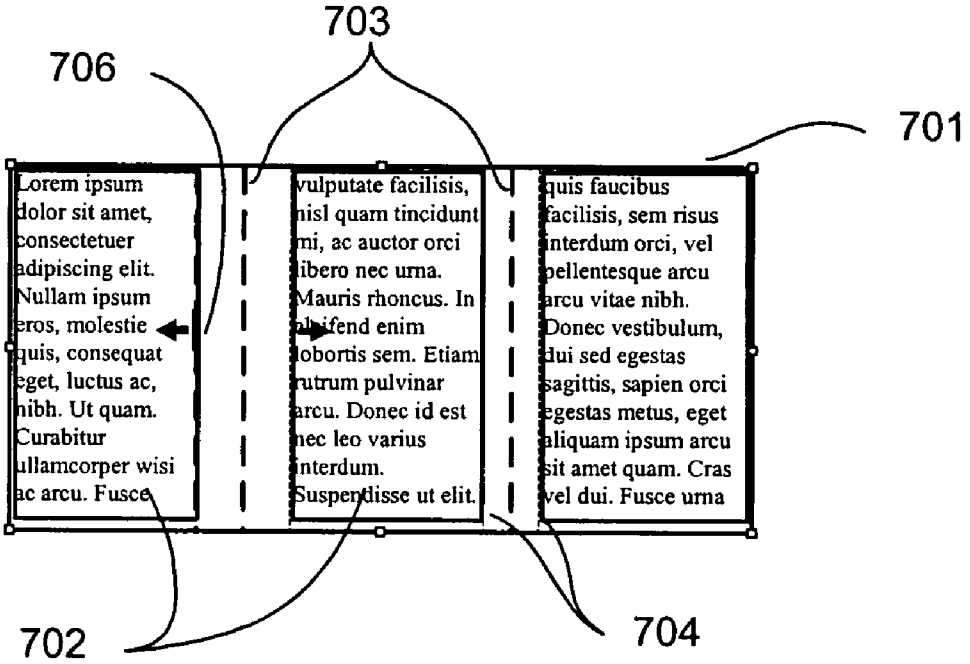

703
706
701
Lorem ipsum
dolor sit amet,
consectetuer
adipiscing elit.
Nullam ipsum
eros, molestie
quis, consequat
eget, luctus ac,
nibh. Ut quam.
Curabitur
ullamcorper wisi
ac arcu. Fusce
vulputate facilisis,
nisl quam tincidunt
mi, ac auctor orci
libero nec urna.
Mauris rhoncus. In
eleifend enim
lobortis sem. Etiam
rutrum pulvinar
arcu. Donec id est
nec leo varius
interdum.
Suspendisse ut elit.
quis faucibus
facilisis, sem risus
interdum orci, vel
pellentesque arcu
arcu vitae nibh.
Donec vestibulum,
dui sed egestas
sagittis, sapien orci
egestas metus, eget
aliquam ipsum arcu
sit amet quam. Cras
vel dui. Fusce urna
702
704

Fig. 7B

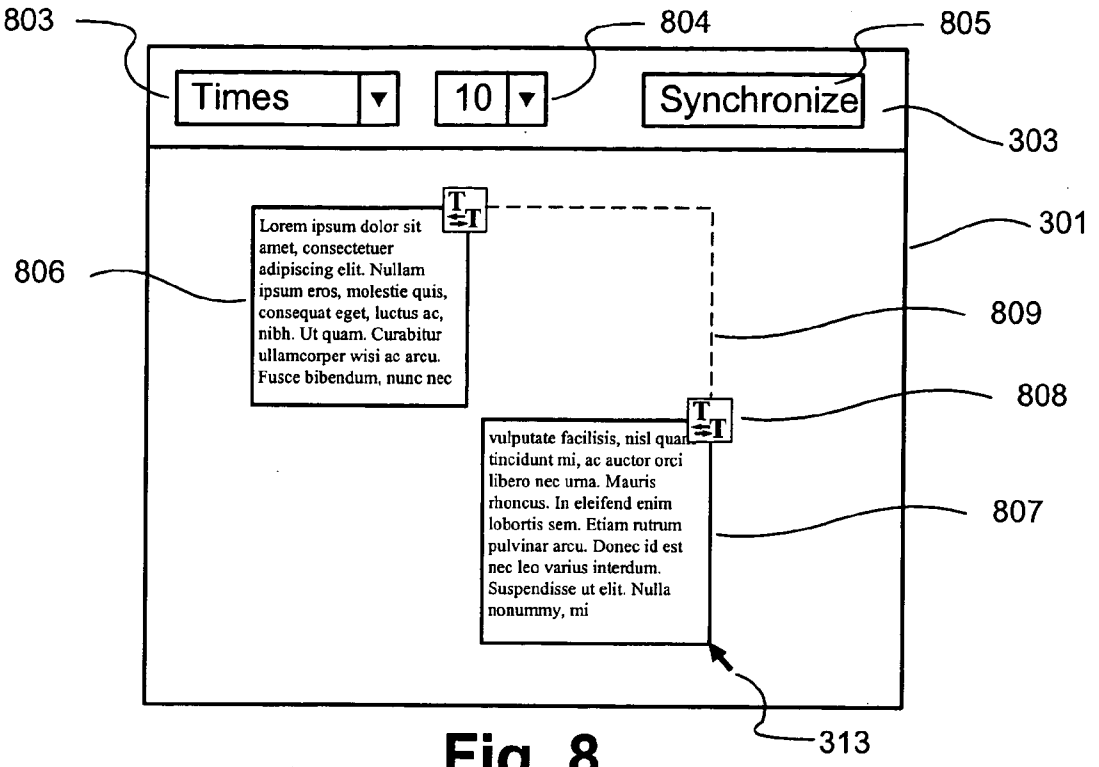

803
804
805
Times
10
Synchronize
303
301
806
Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Nullam ipsum eros, molestie quis, consequat eget, luctus ac, nibh. Ut quam. Curabitur ullamcorper wisi ac arcu. Fusce bibendum, nunc nec
809
808
vulputate facilisis, nisl quam tincidunt mi, ac auctor orci libero nec urna. Mauris rhoncus. In eleifend enim lobortis sem. Etiam rutrum pulvinar arcu. Donec id est nec leo varius interdum. Suspendisse ut elit. Nulla nonummy, mi
807
313

Fig. 8

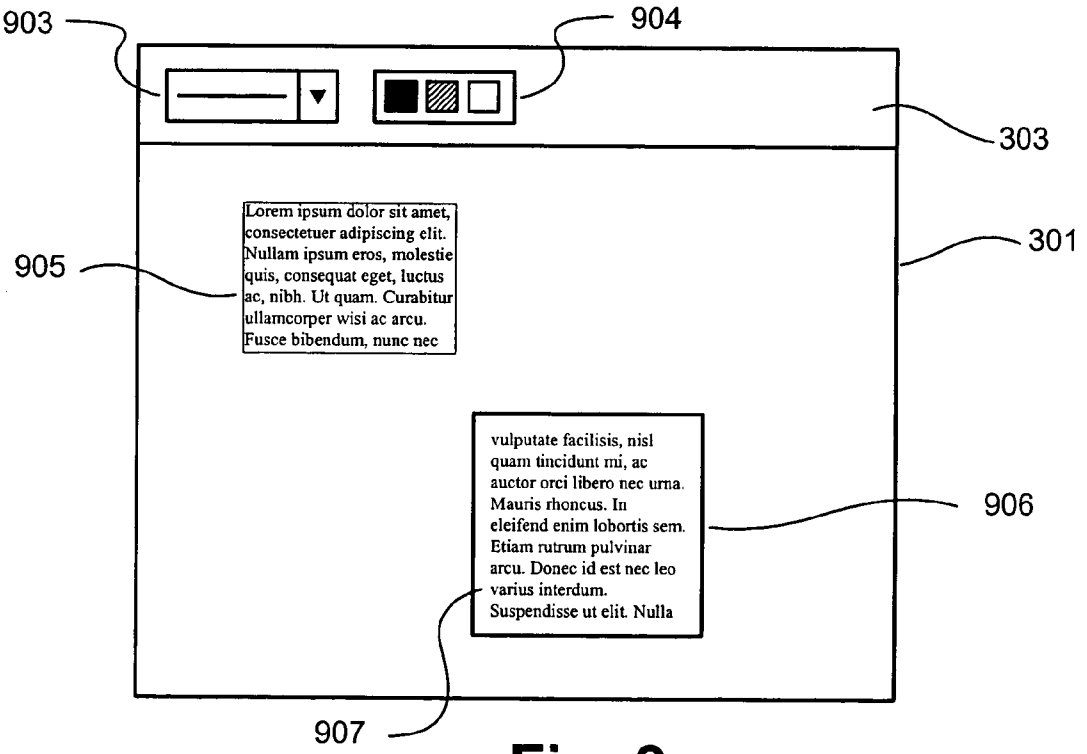

903
904
303
301
905
Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Nullam ipsum eros, molestie quis, consequat eget, luctus ac, nibh. Ut quam. Curabitur ullamcorper wisi ac arcu. Fusce bibendum, nunc nec
vulputate facilisis, nisl quam tincidunt mi, ac auctor orci libero nec urna. Mauris rhoncus. In eleifend enim lobortis sem. Etiam rutrum pulvinar arcu. Donec id est nec leo varius interdum. Suspendisse ut elit. Nulla
906
907

Fig. 9

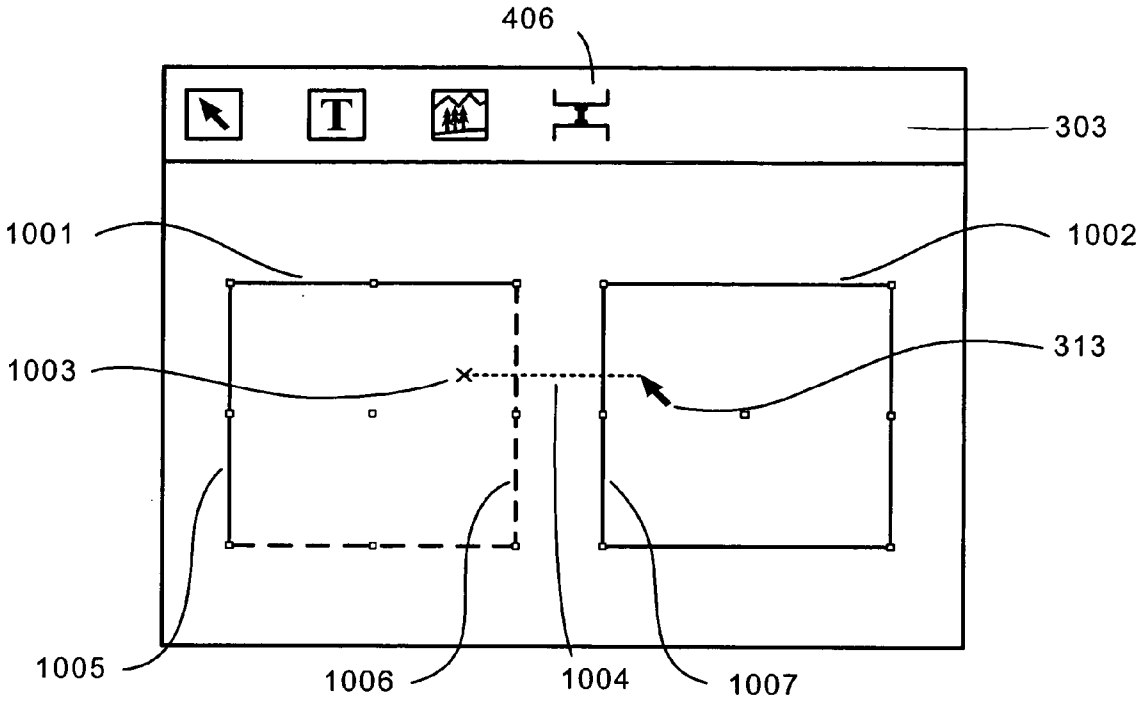

406
303
1001
1002
1003
313
1005
1006
1004
1007

Fig. 10

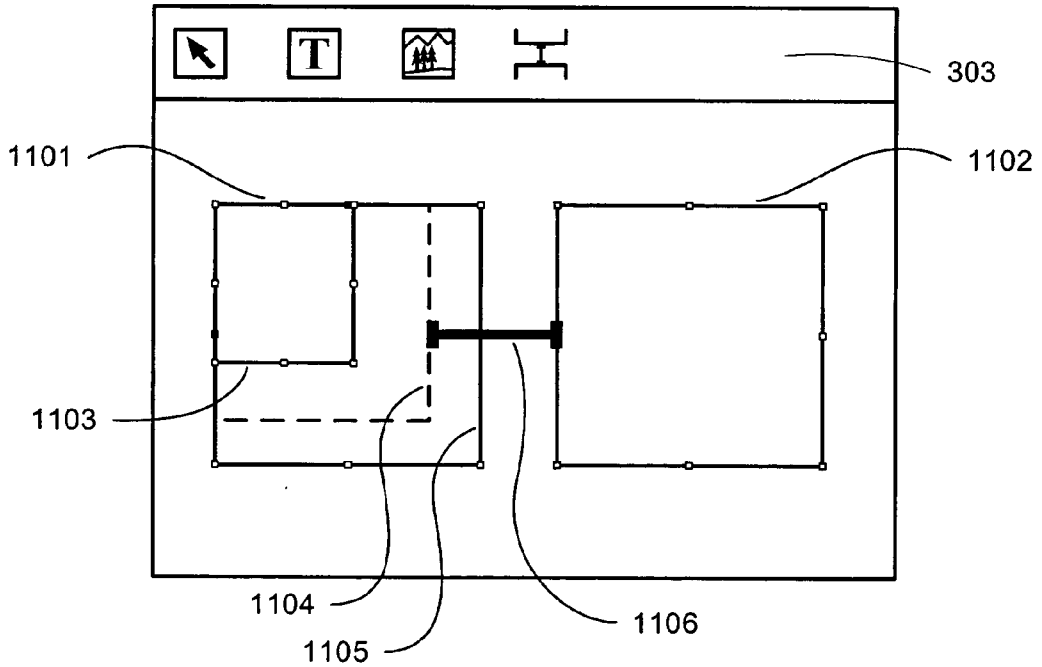

303
1101
1102
1103
1104
1105
1106

Fig. 11

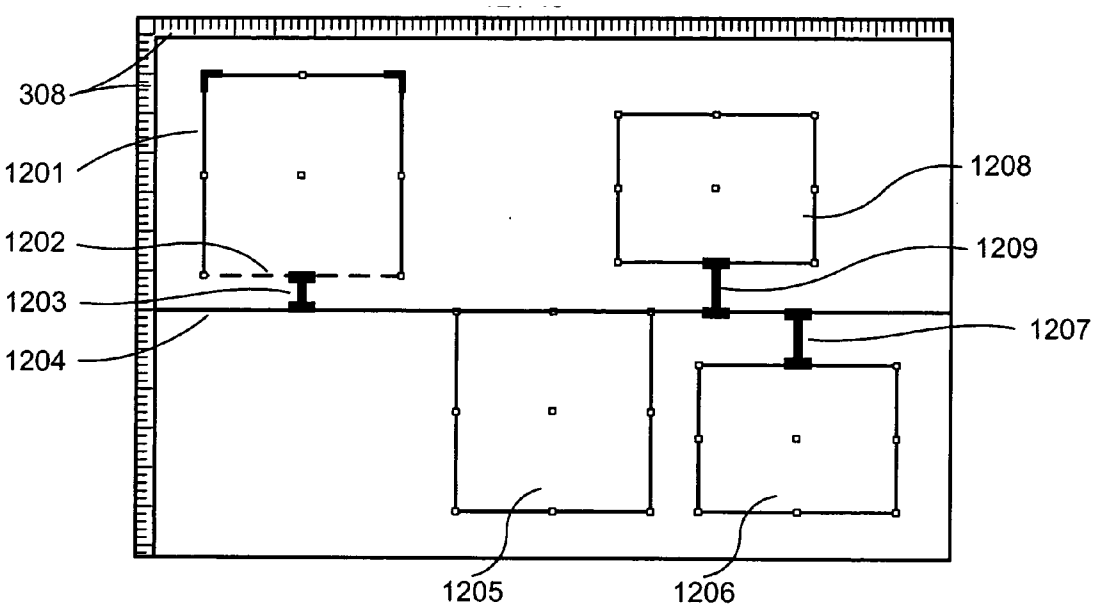

308
1201
1202
1203
1204
1208
1209
1207
1205
1206

Fig. 12

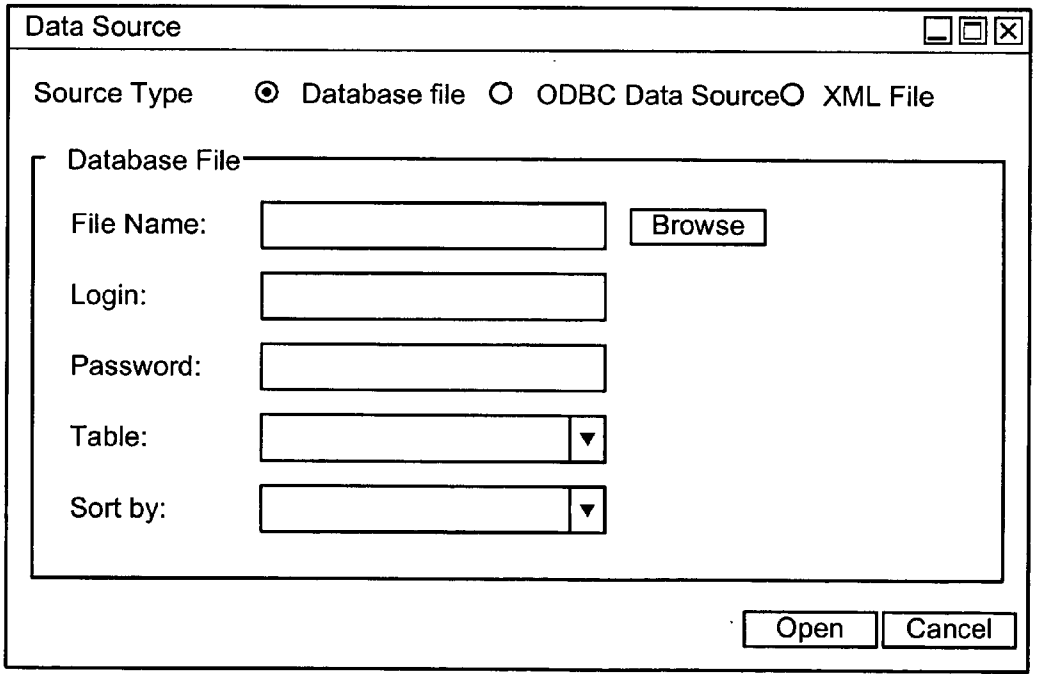

Data Source
Source Type
Database file
ODBC Data Source
XML File
Database File
File Name:
Browse
Login:
Password:
Table:
Sort by:
Open
Cancel

Fig. 13

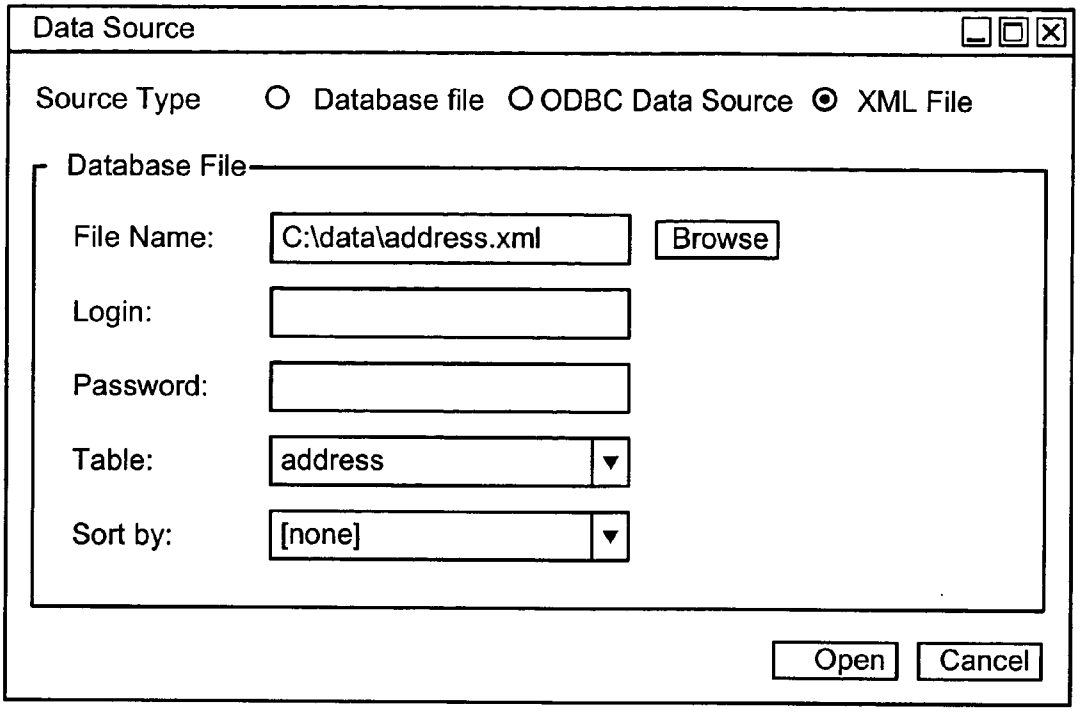

Data Source
Source Type
Database file
ODBC Data Source
XML File
Database File
File Name:
C:\data\address.xml
Browse
Login:
Password:
Table:
address
Sort by:
[none]
Open
Cancel

Fig. 14

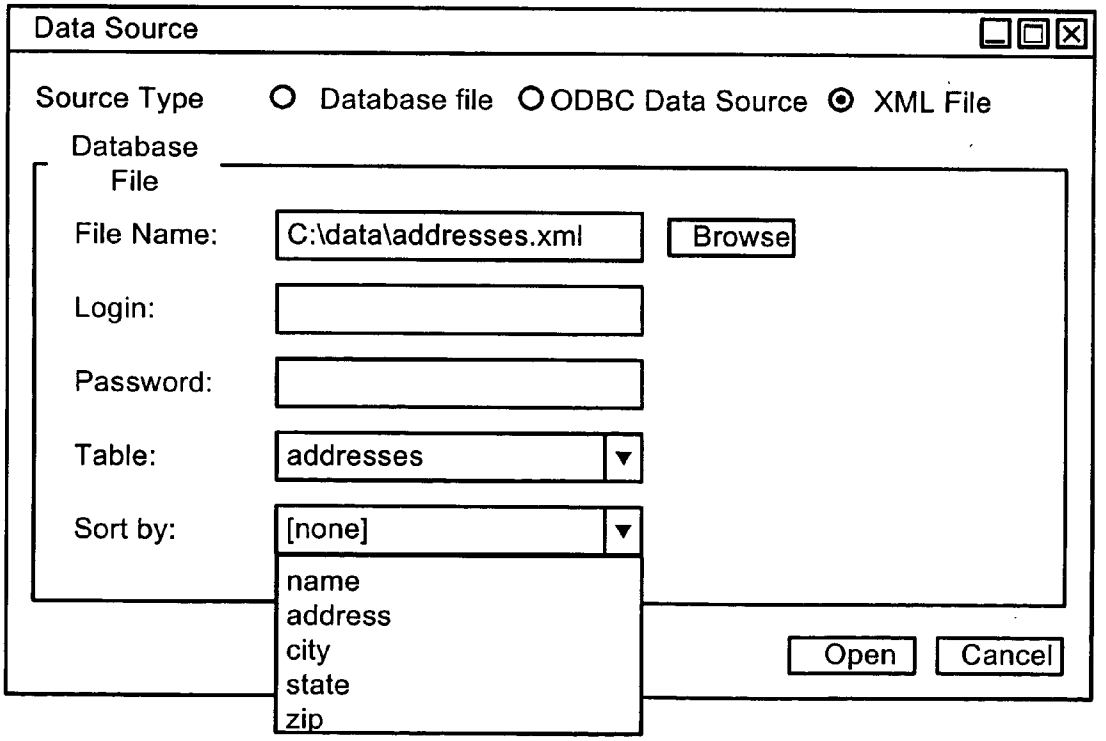

Data Source
Source Type
Database file
ODBC Data Source
XML File
Database File
File Name:
C:\data\addresses.xml
Browse
Login:
Password:
Table:
addresses
Sort by:
[none]
name
address
city
state
zip
Open
Cancel

Fig. 15

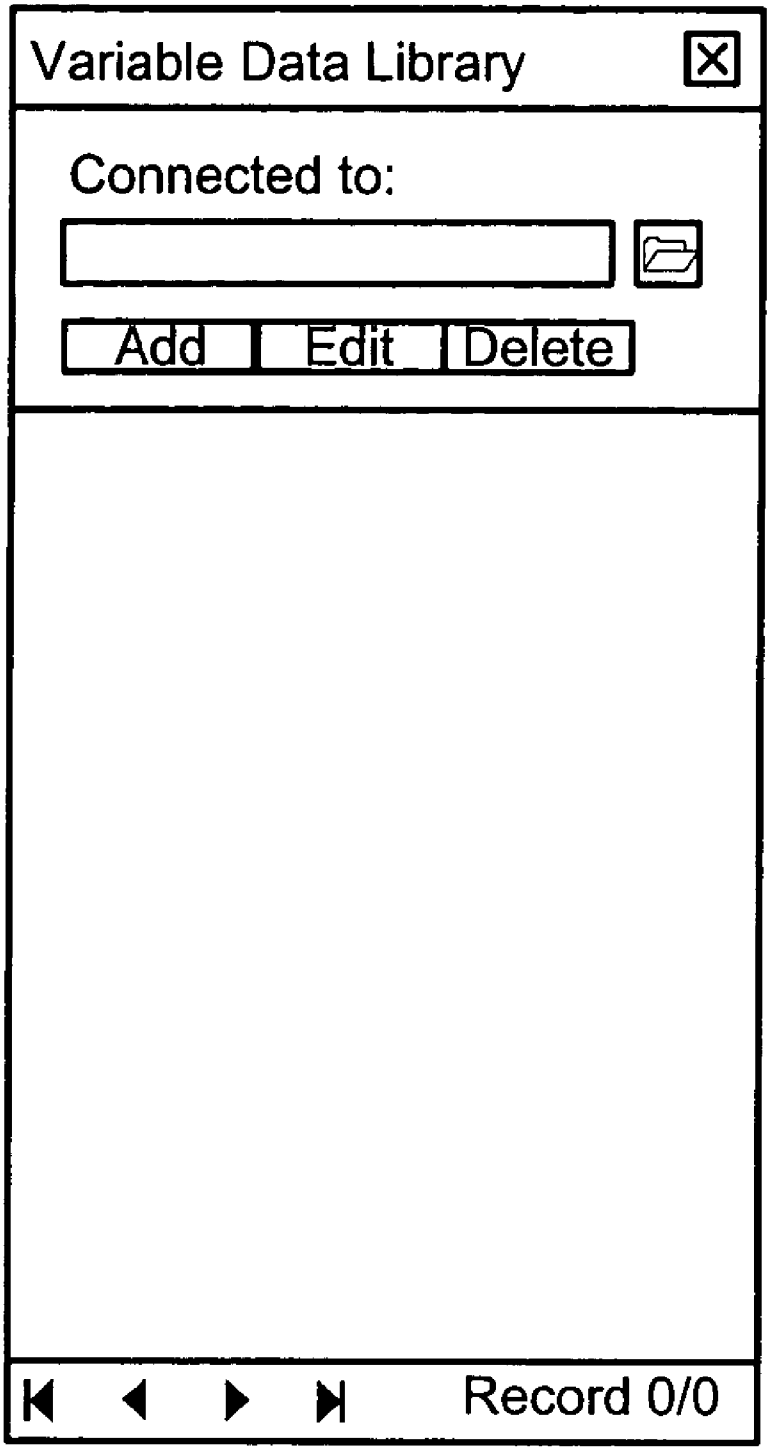

Variable Data Library
Connected to:
Add
Edit
Delete
Record 0/0

Fig. 16

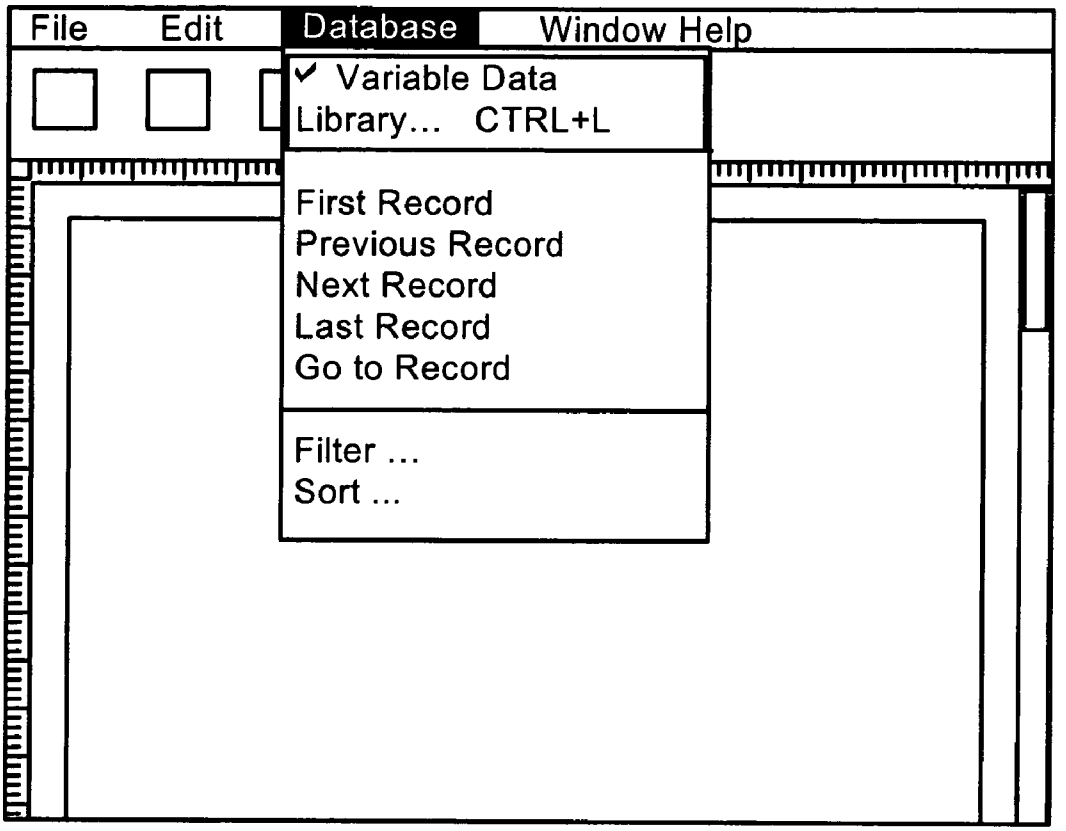

File
Edit
Database
Window Help
✔ Variable Data
Library... CTRL+L
First Record
Previous Record
Next Record
Last Record
Go to Record
Filter ...
Sort ...

Fig. 17

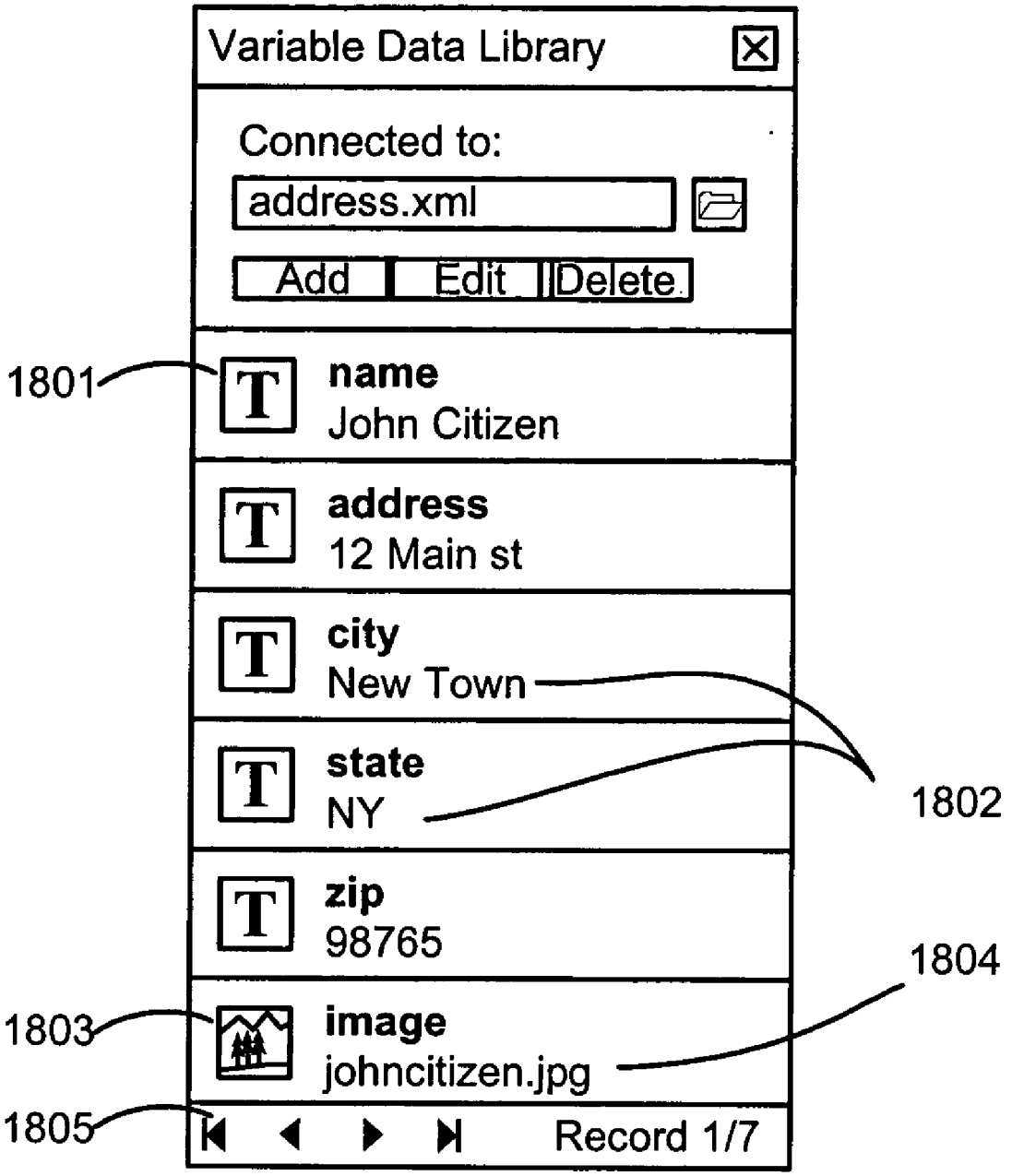

Variable Data Library
Connected to:
address.xml
Add
Edit
Delete
1801
name
John Citizen
address
12 Main st
city
New Town
state
NY
1802
zip
98765
1804
1803
image
johncitizen.jpg
1805
Record 1/7

Fig. 18

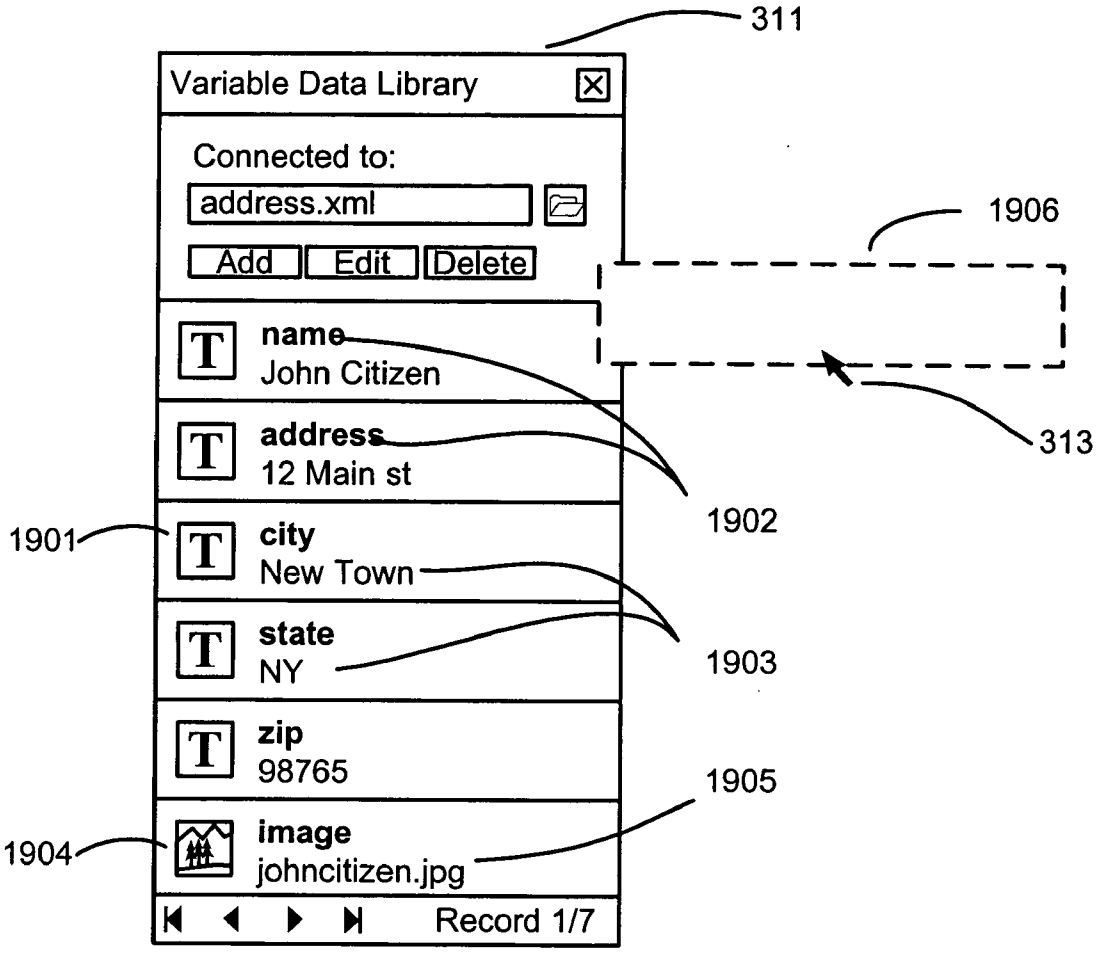

311
Variable Data Library
Connected to:
address.xml
Add
Edit
Delete
1906
name
John Citizen
address
12 Main st
313
1902
1901
city
New Town
state
NY
1903
zip
98765
1905
1904
image
johncitizen.jpg
Record 1/7

Fig. 19

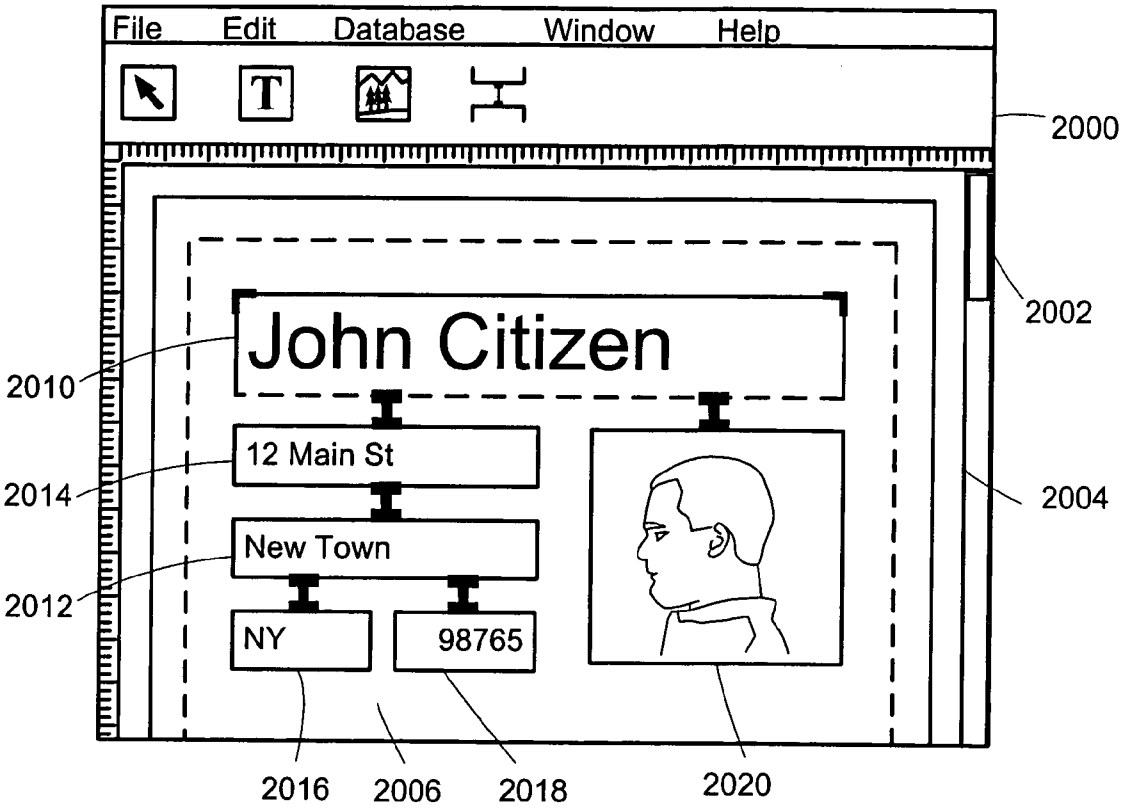

File
Edit
Database
Window
Help
T
2000
2002
John Citizen
2010
12 Main St
2014
2004
New Town
2012
NY
98765
2016
2006
2018
2020

Fig. 20

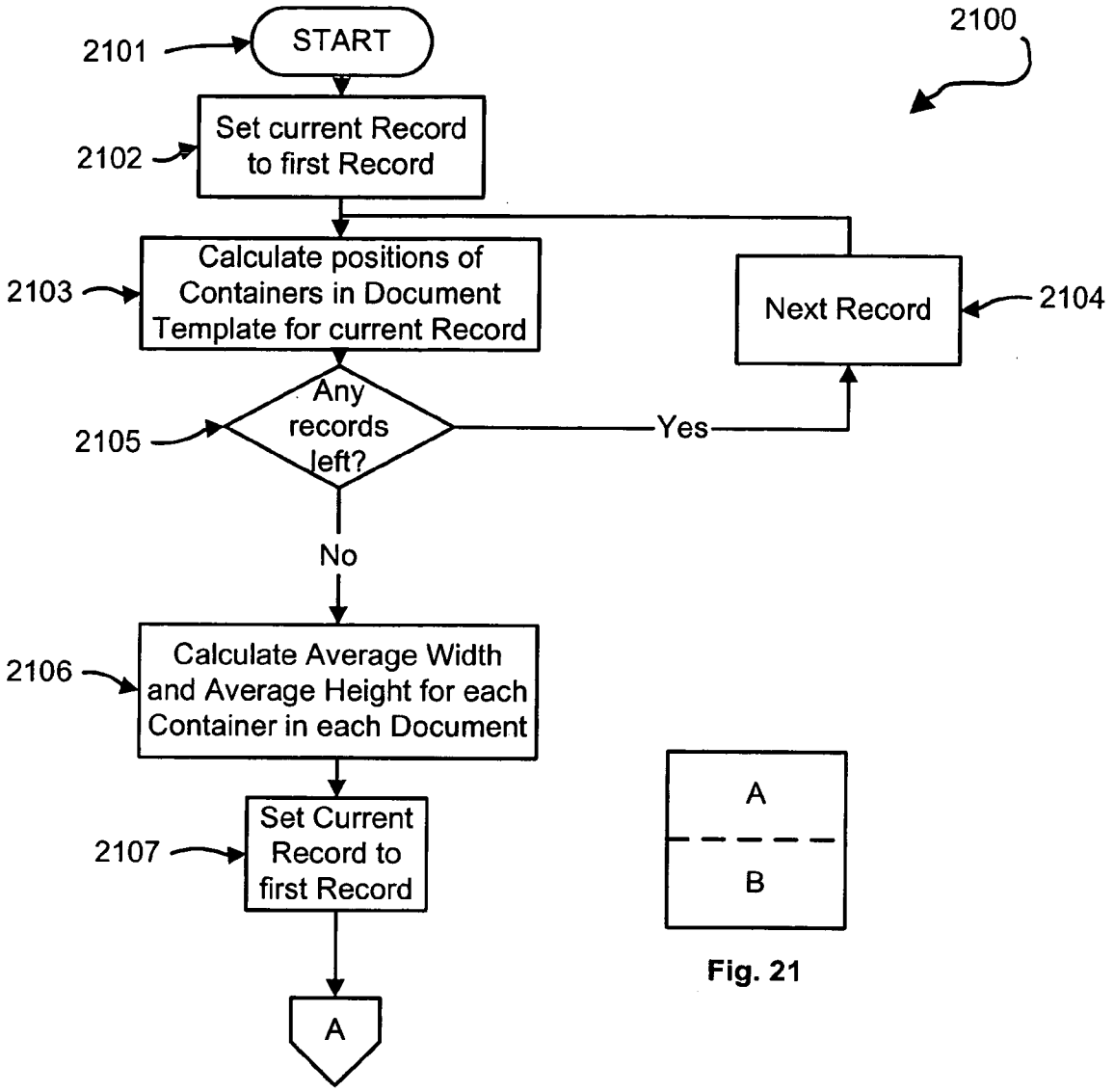


Fig. 21

Fig. 21A

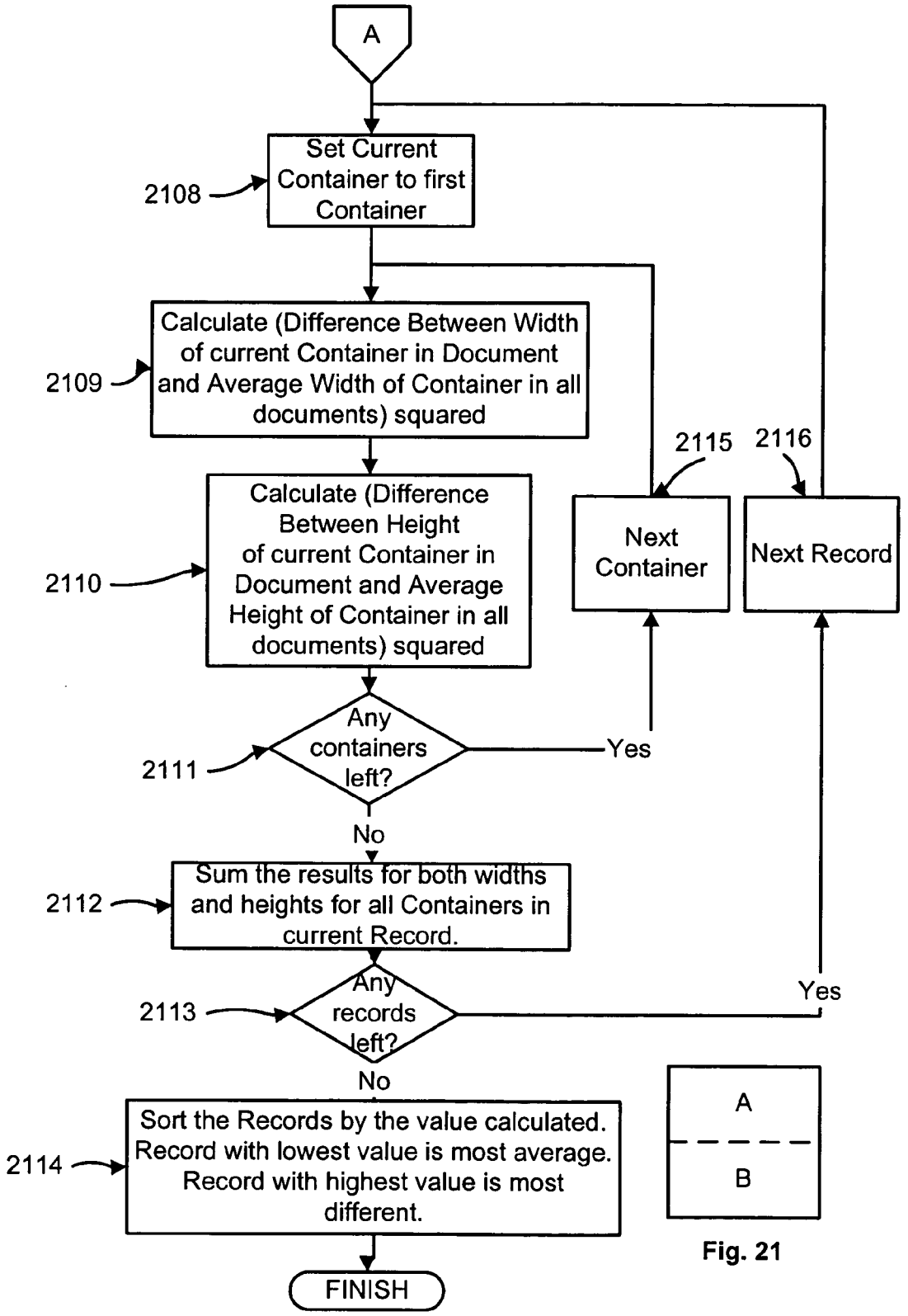


Fig. 21

Fig. 21B

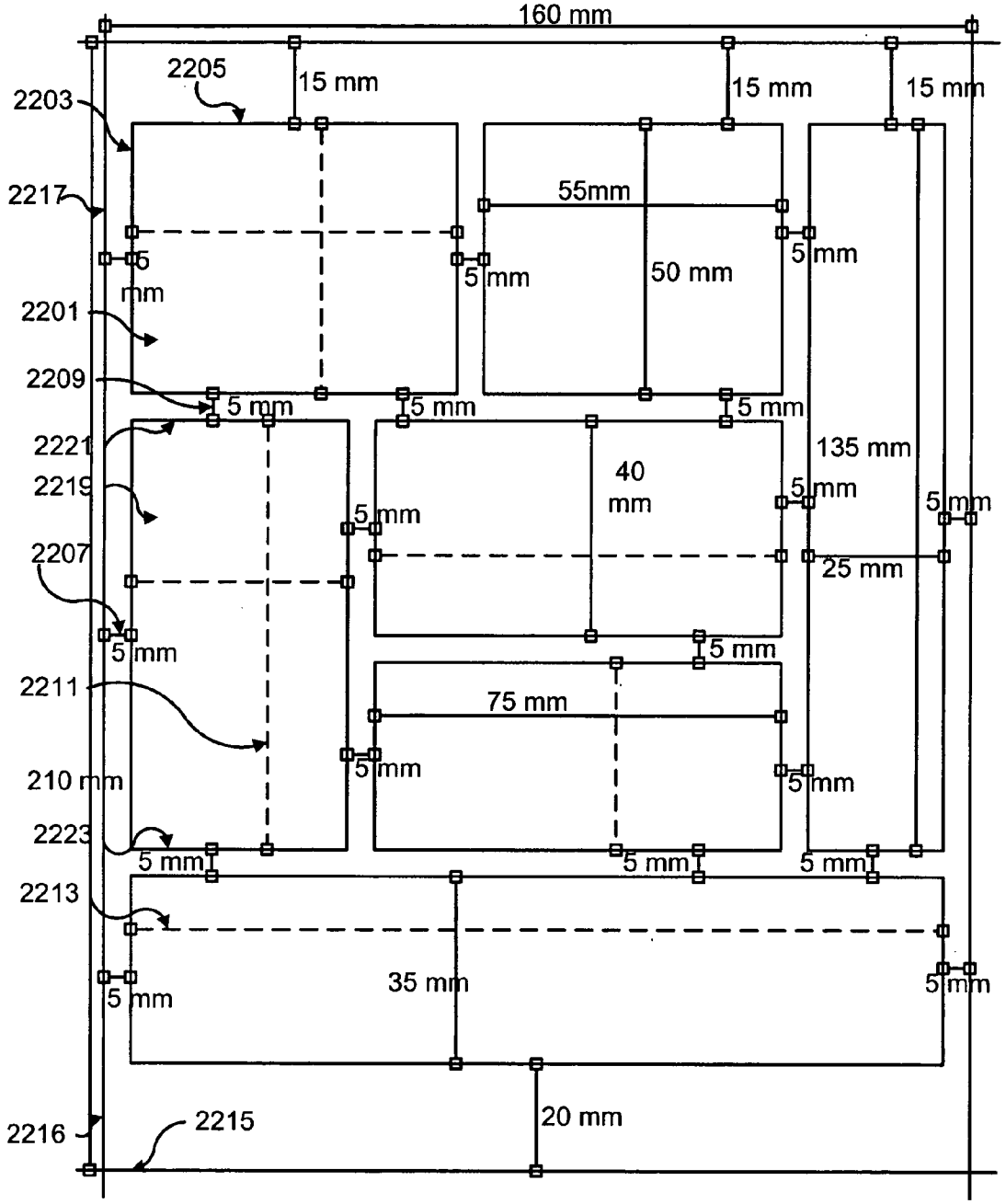

160 mm
2205
15 mm
15 mm
15 mm
2203
2217
55mm
5 mm
5 mm
50 mm
5 mm
2201
2209
5 mm
5 mm
5 mm
2221
135 mm
40 mm
2219
5 mm
5 mm
5 mm
2207
25 mm
5 mm
5 mm
2211
75 mm
5 mm
210 mm
5 mm
2223
5 mm
5 mm
5 mm
2213
35 mm
5 mm
5 mm
20 mm
2216
2215

Fig. 22

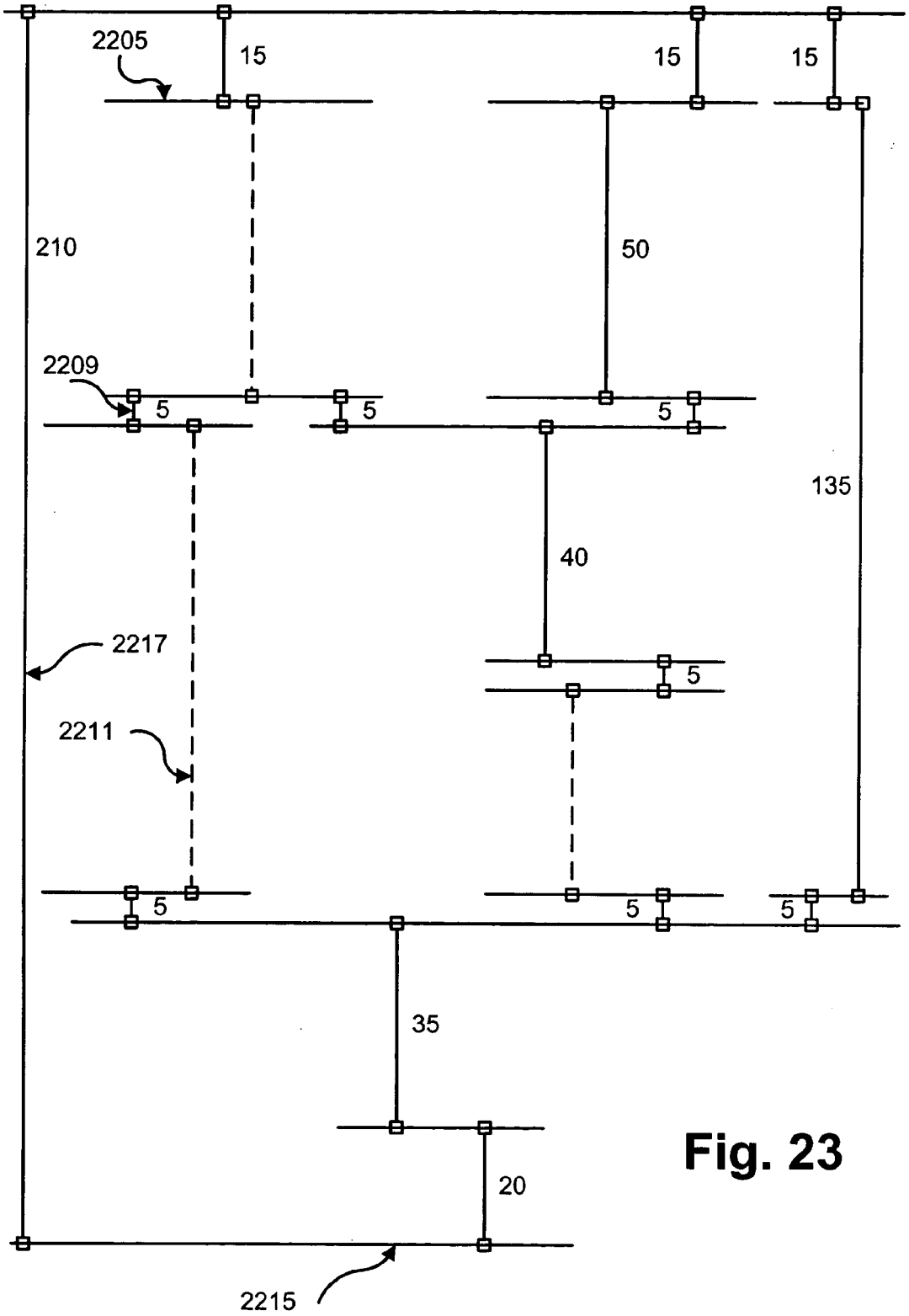


Fig. 23

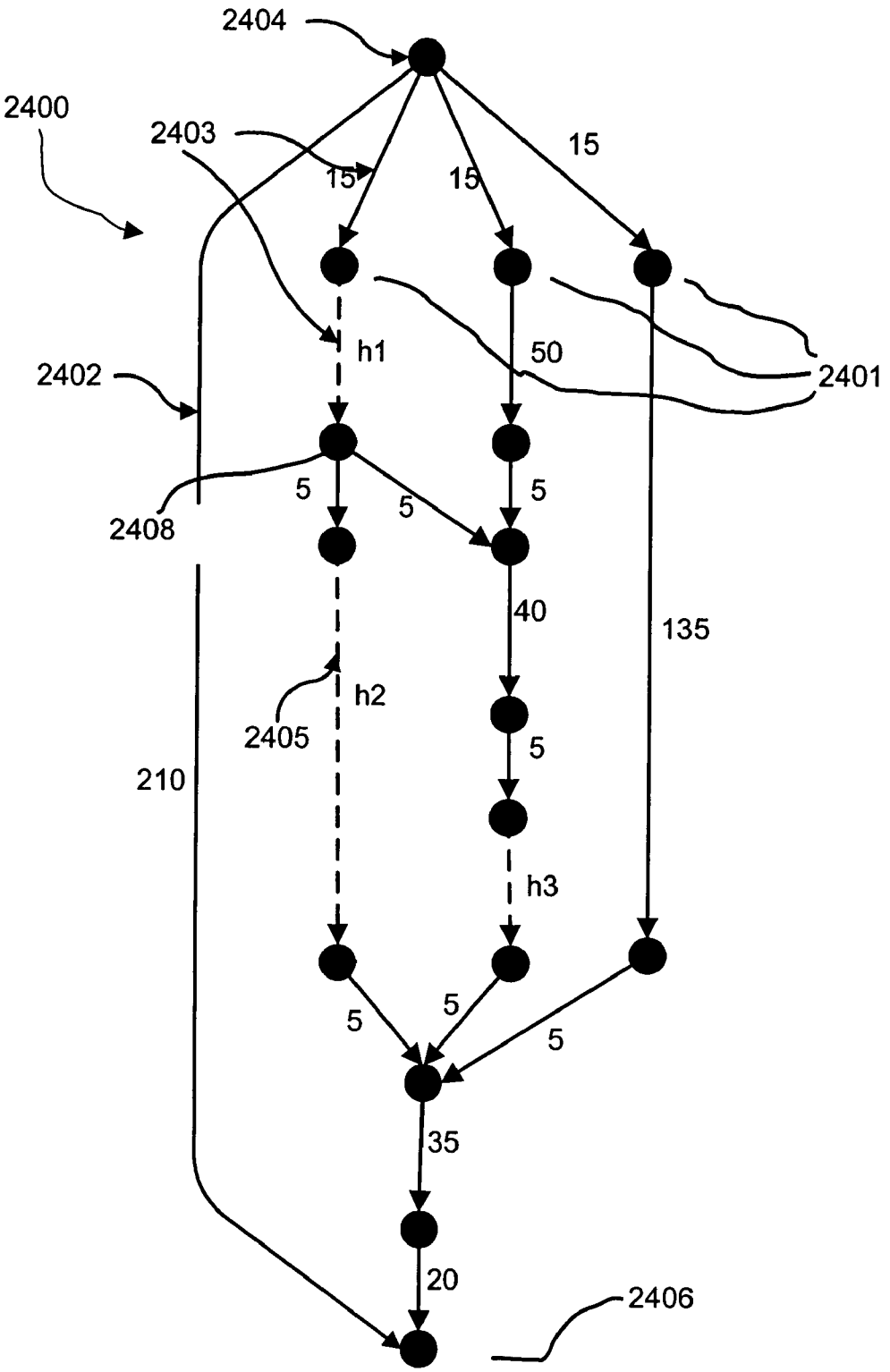

2404
2400
2403
15
15
15
h1
50
2401
2402
5
5
5
2408
40
135
h2
2405
5
210
h3
5
5
5
35
20
2406

Fig. 24

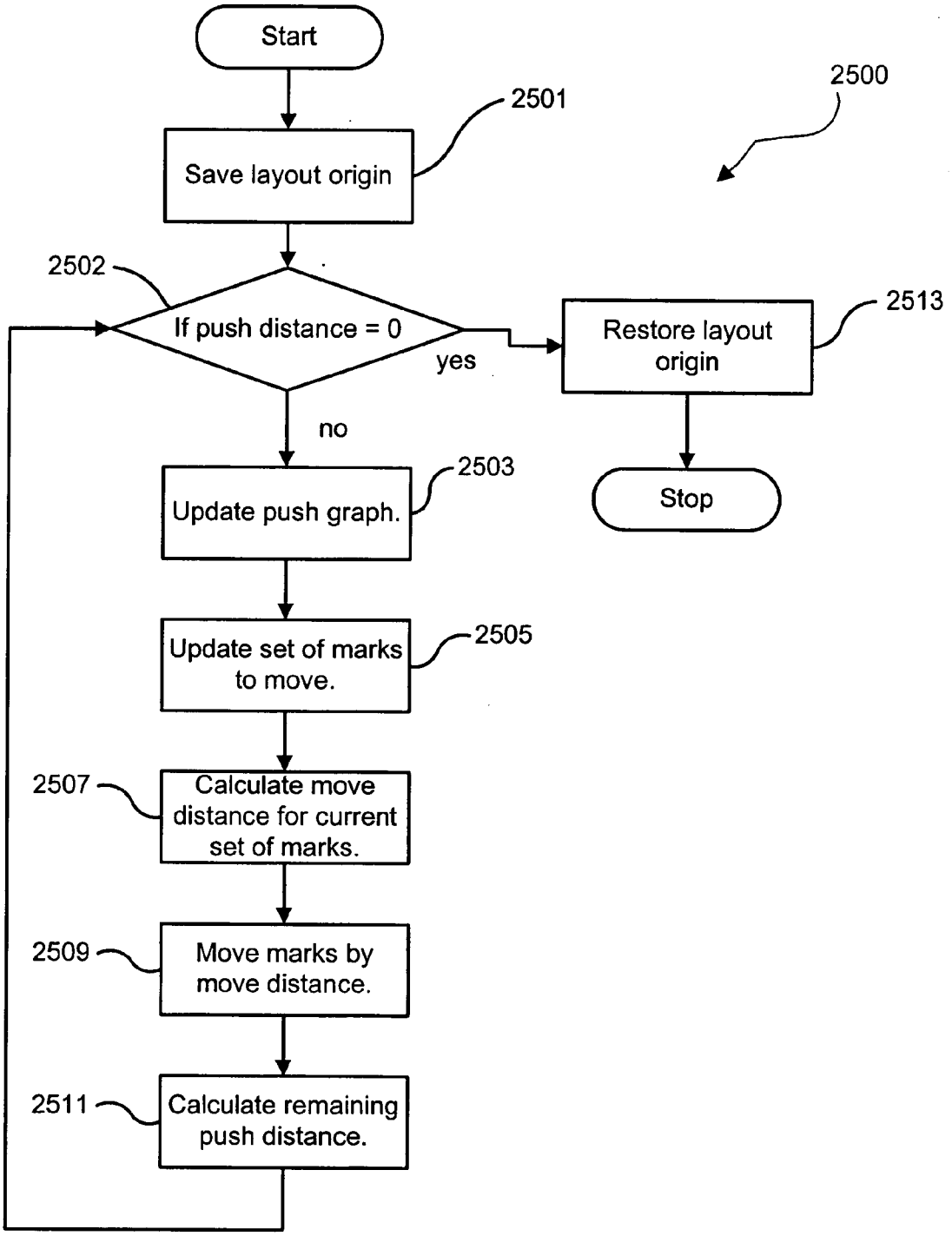

Start
2500
2501
Save layout origin
2502
If push distance = 0
yes
Restore layout origin
2513
no
Stop
2503
Update push graph.
2505
Update set of marks to move.
2507
Calculate move distance for current set of marks.
2509
Move marks by move distance.
2511
Calculate remaining push distance.

Fig. 25

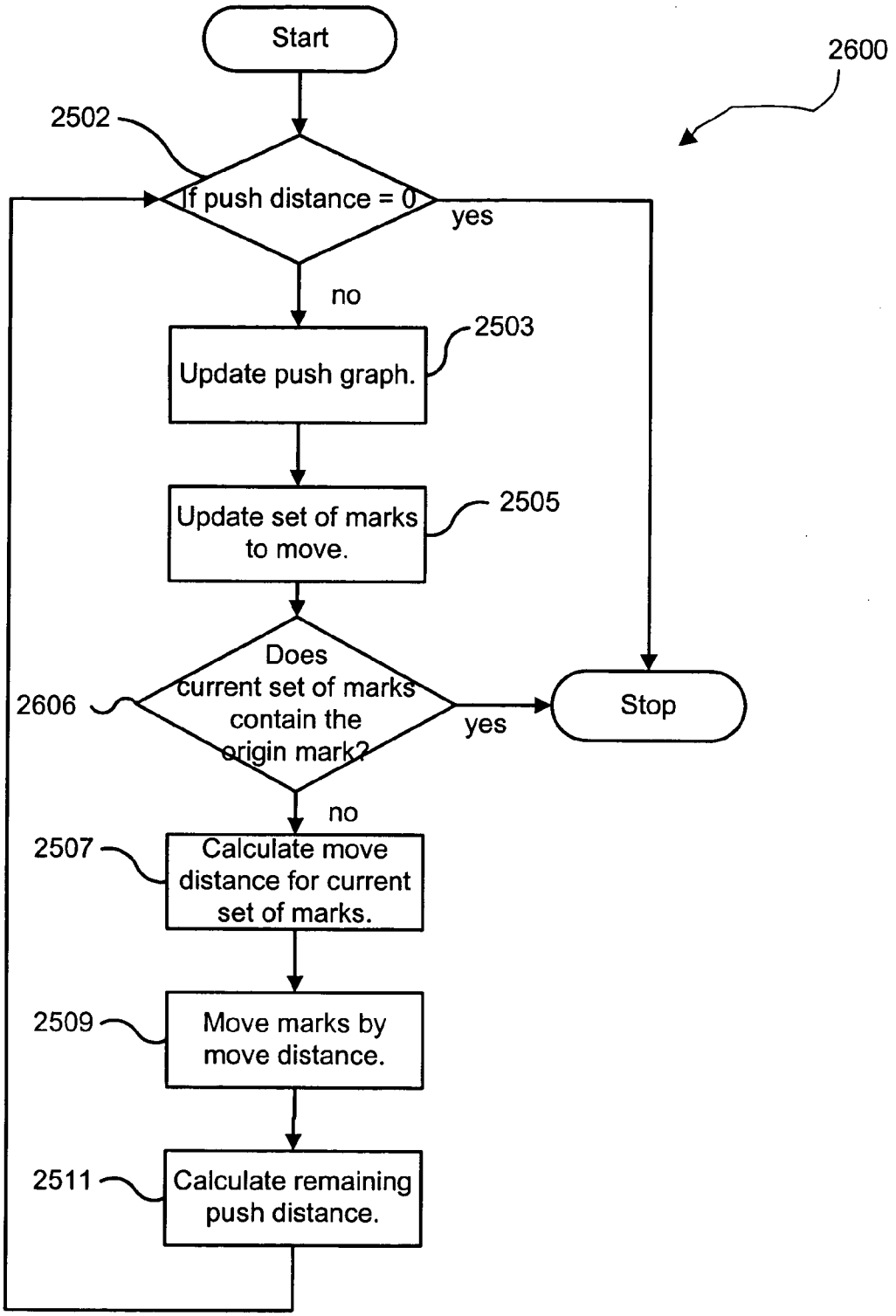

Start
2600
2502
If push distance = 0
yes
no
2503
Update push graph.
2505
Update set of marks to move.
2606
Does current set of marks contain the origin mark?
yes
Stop
no
2507
Calculate move distance for current set of marks.
2509
Move marks by move distance.
2511
Calculate remaining push distance.

Fig. 26

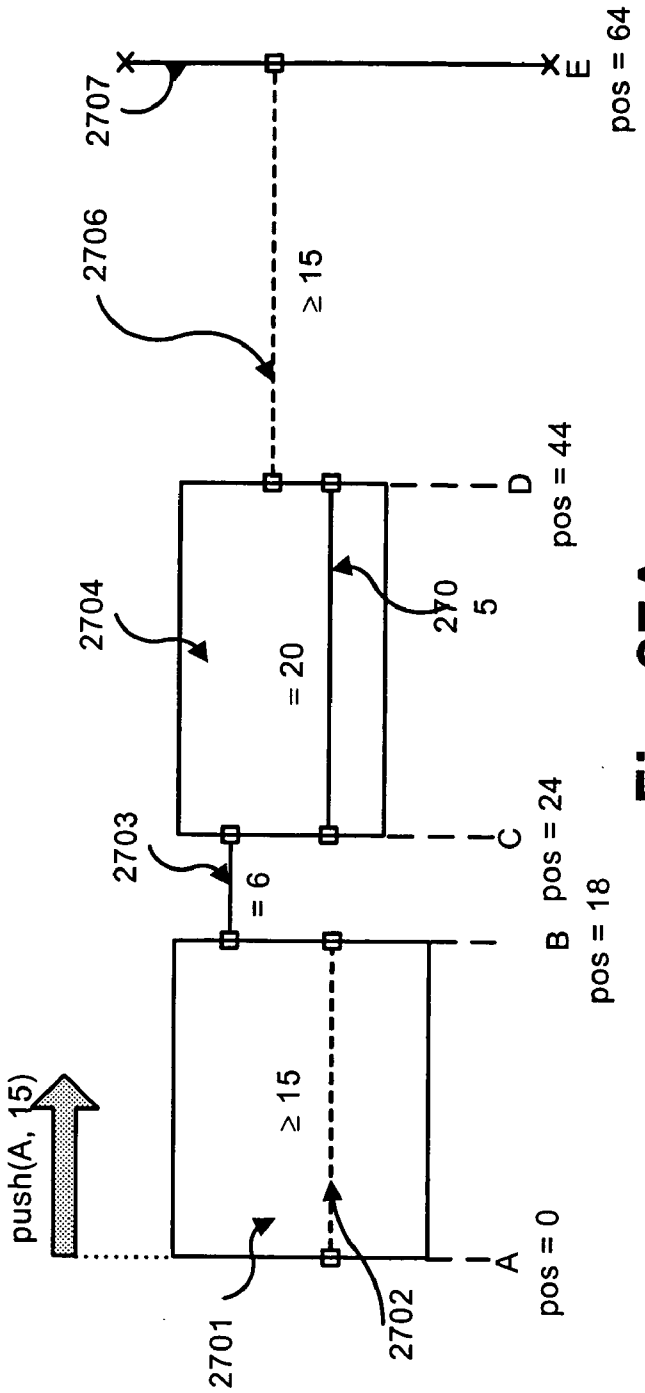


Fig. 27A

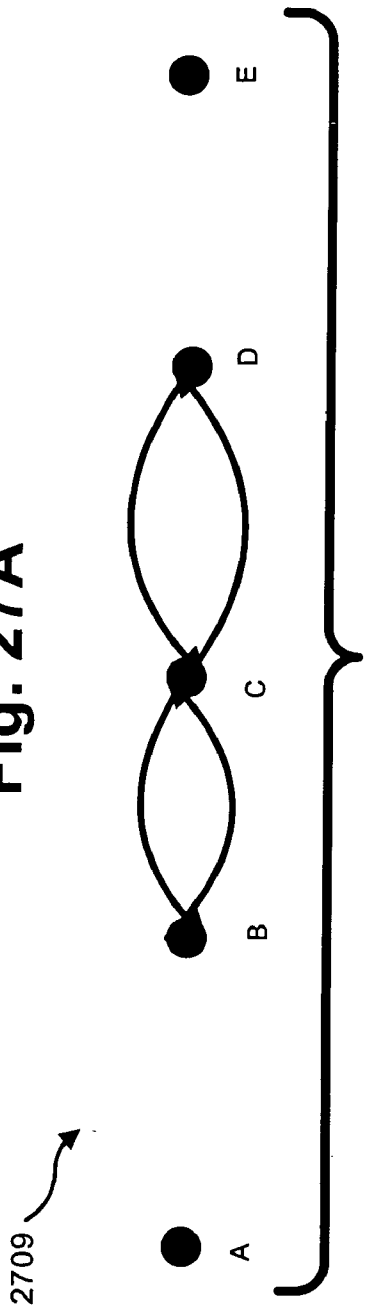


Fig. 27B

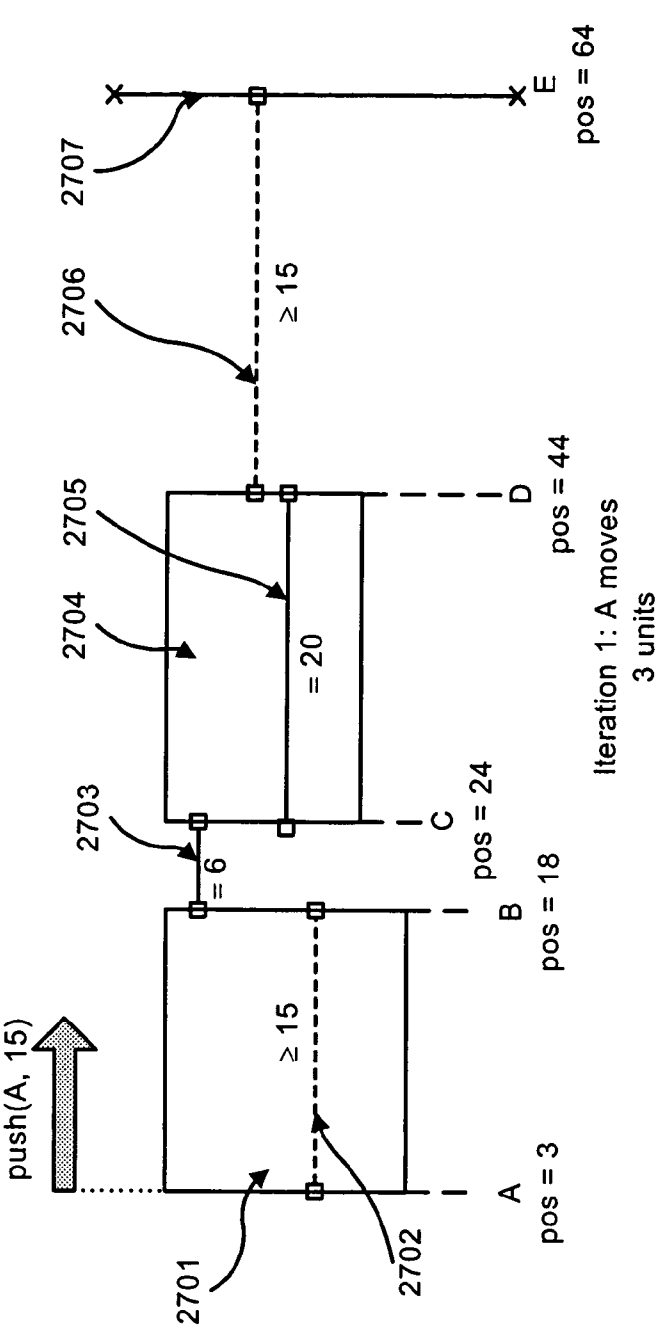


Fig. 27C

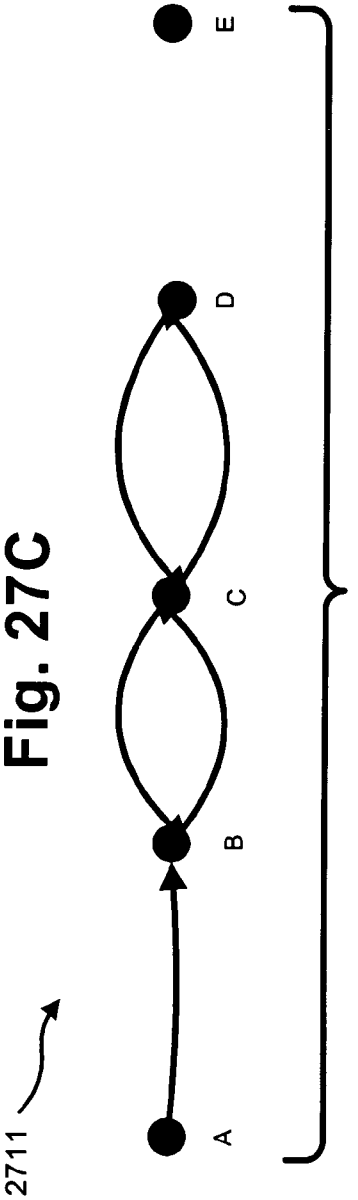
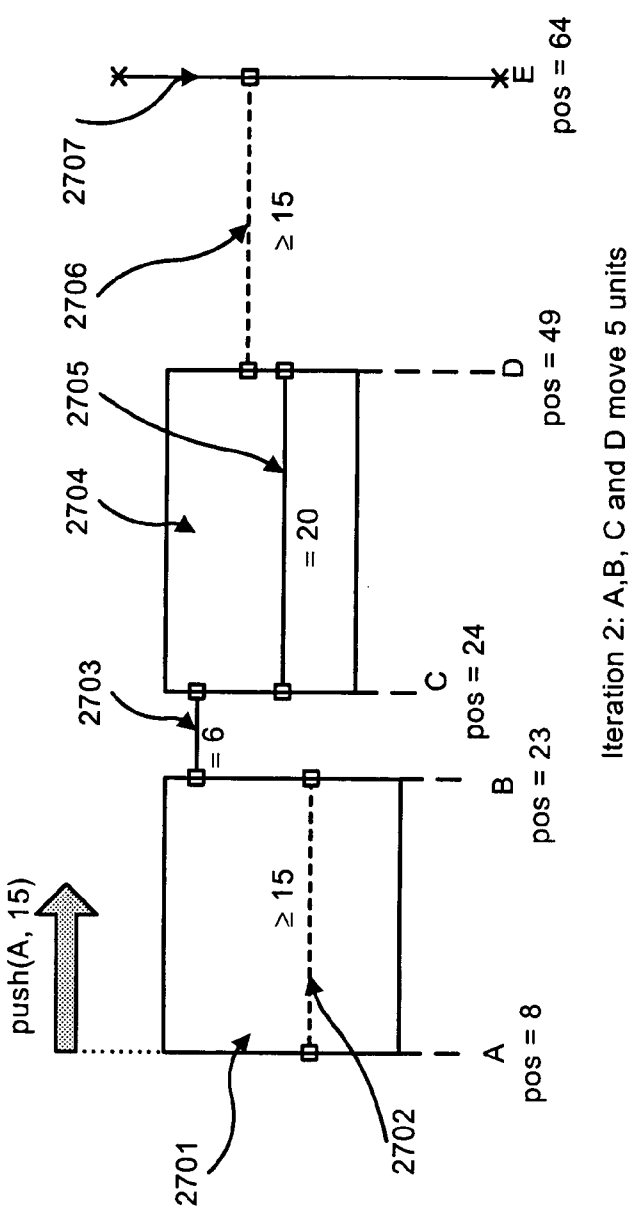


Fig. 27D



Iteration 2: A,B, C and D move 5 units

Fig. 27E

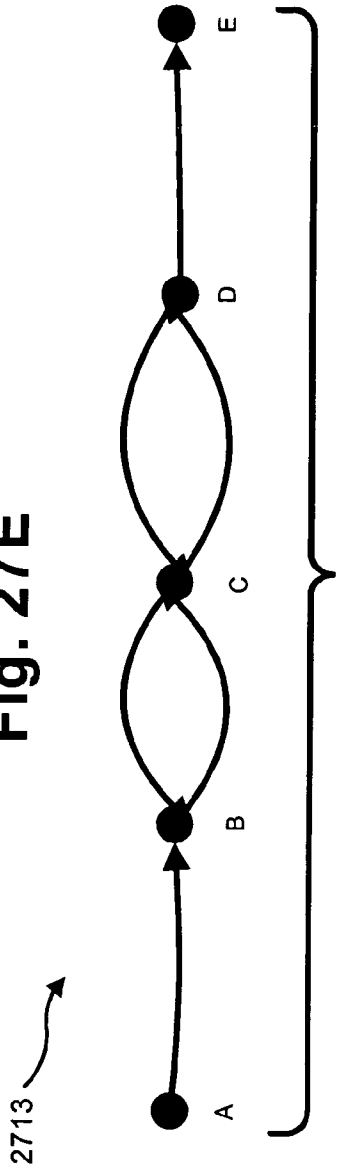


Fig. 27F

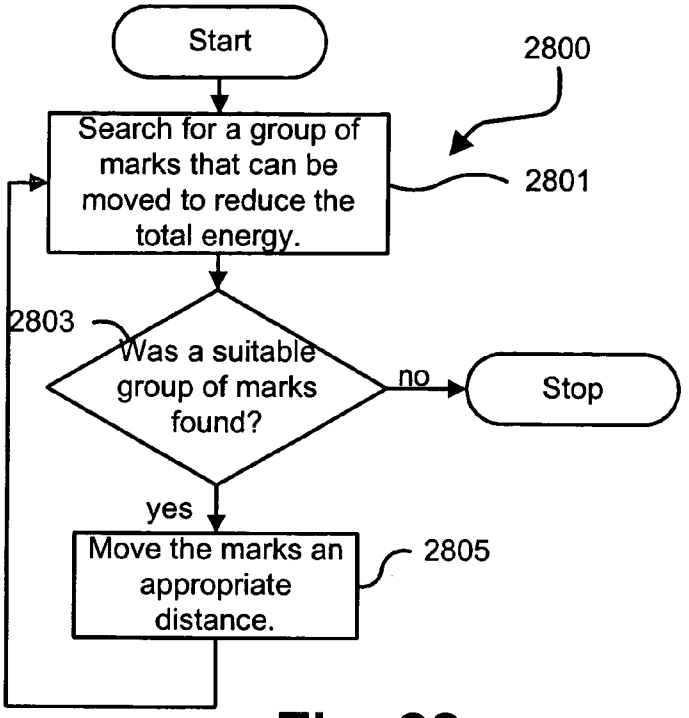

Start
2800
Search for a group of marks that can be moved to reduce the total energy.
2801
2803
Was a suitable group of marks found?
no
Stop
yes
Move the marks an appropriate distance.
2805

Fig. 28

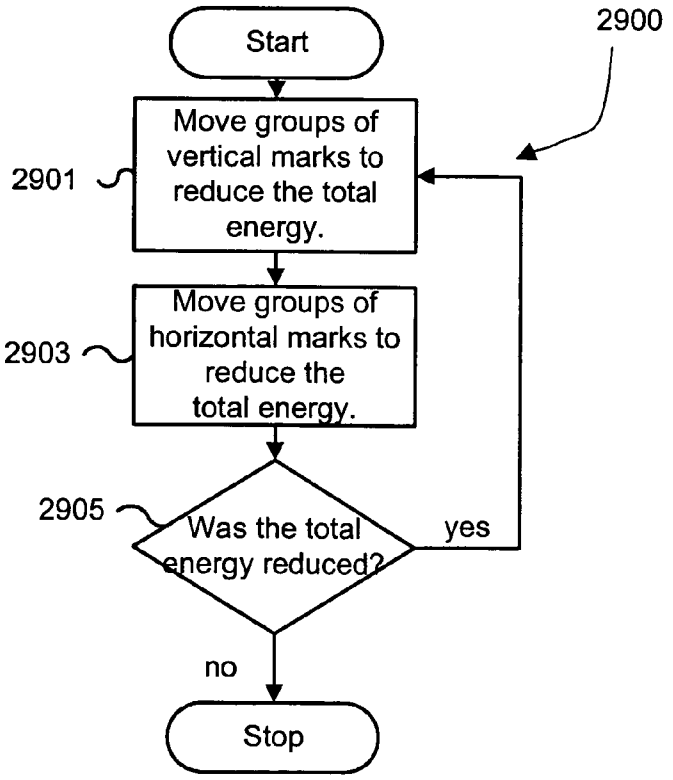

Start
2900
Move groups of vertical marks to reduce the total energy.
2901
Move groups of horizontal marks to reduce the total energy.
2903
2905
Was the total energy reduced?
yes
no
Stop

Fig. 29

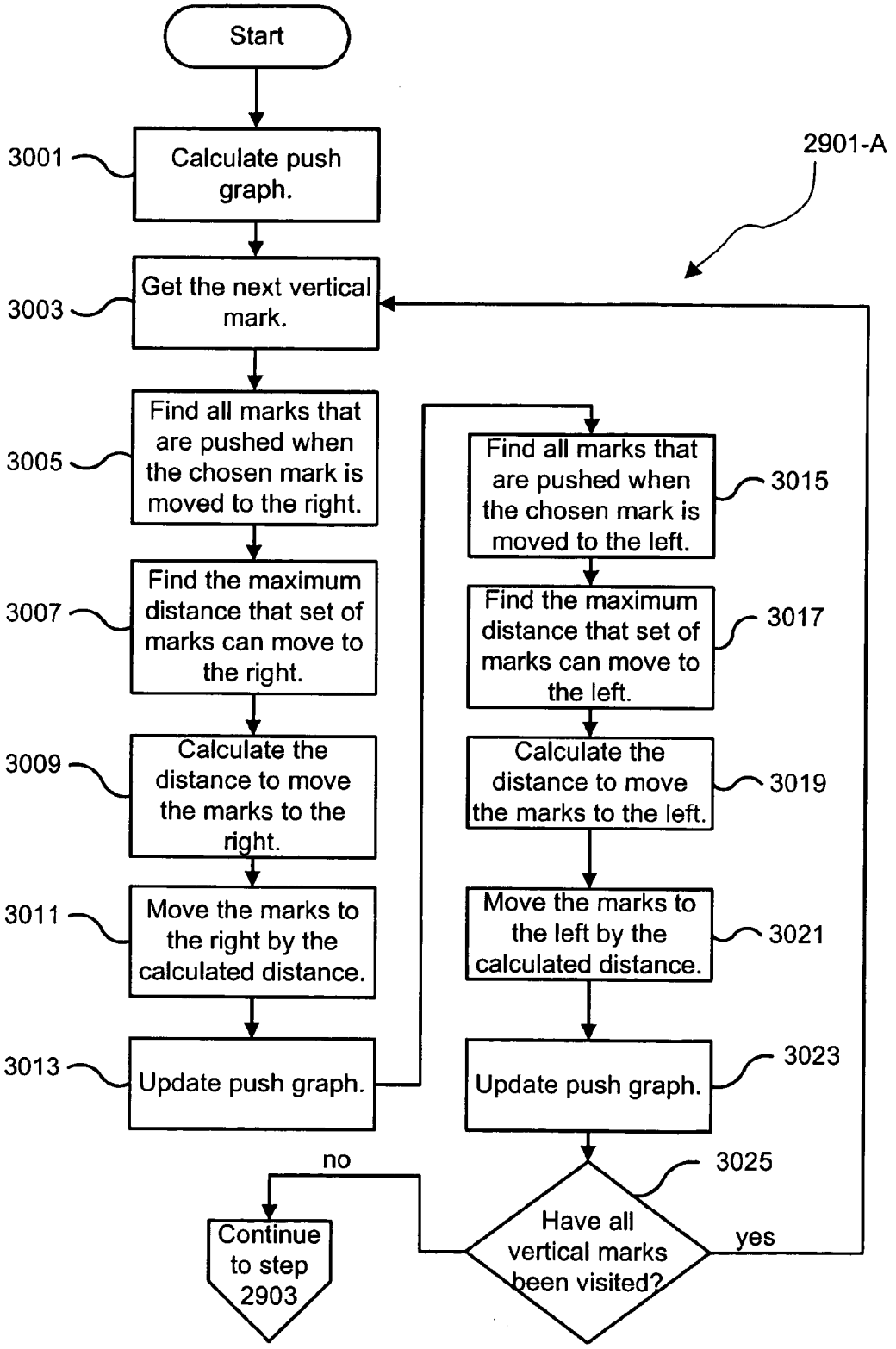

Start
3001
Calculate push graph.
2901-A
3003
Get the next vertical mark.
3005
Find all marks that are pushed when the chosen mark is moved to the right.
3007
Find the maximum distance that set of marks can move to the right.
3009
Calculate the distance to move the marks to the right.
3011
Move the marks to the right by the calculated distance.
3013
Update push graph.
3015
Find all marks that are pushed when the chosen mark is moved to the left.
3017
Find the maximum distance that set of marks can move to the left.
3019
Calculate the distance to move the marks to the left.
3021
Move the marks to the left by the calculated distance.
3023
Update push graph.
3025
Have all vertical marks been visited?
no
yes
Continue to step 2903

Fig. 30A

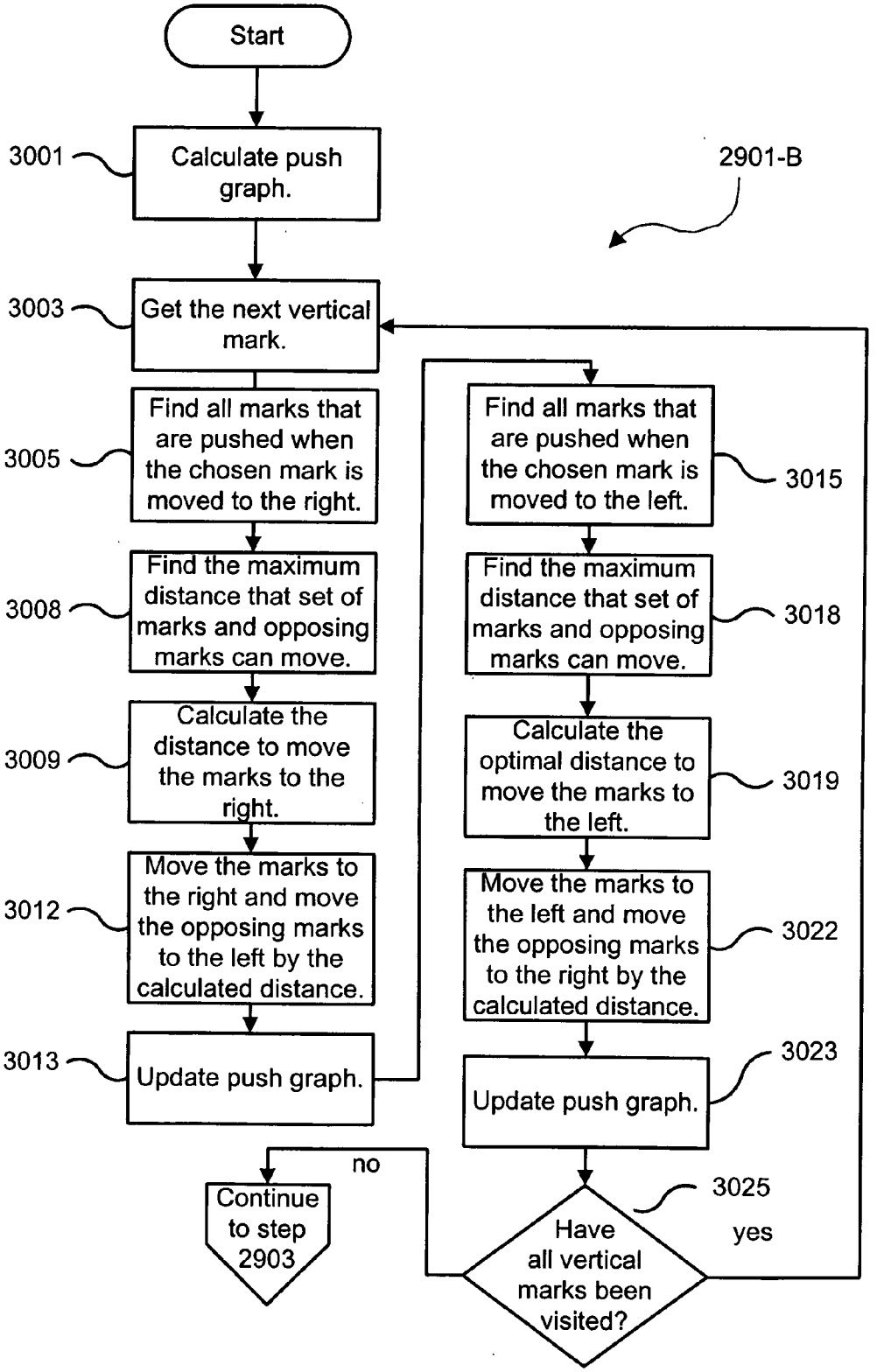

Start
3001
Calculate push graph.
2901-B
3003
Get the next vertical mark.
3005
Find all marks that are pushed when the chosen mark is moved to the right.
3008
Find the maximum distance that set of marks and opposing marks can move.
3009
Calculate the distance to move the marks to the right.
3012
Move the marks to the right and move the opposing marks to the left by the calculated distance.
3013
Update push graph.
3015
Find all marks that are pushed when the chosen mark is moved to the left.
3018
Find the maximum distance that set of marks and opposing marks can move.
3019
Calculate the optimal distance to move the marks to the left.
3022
Move the marks to the left and move the opposing marks to the right by the calculated distance.
3023
Update push graph.
3025
Have all vertical marks been visited?
no
yes
Continue to step 2903

Fig. 30B

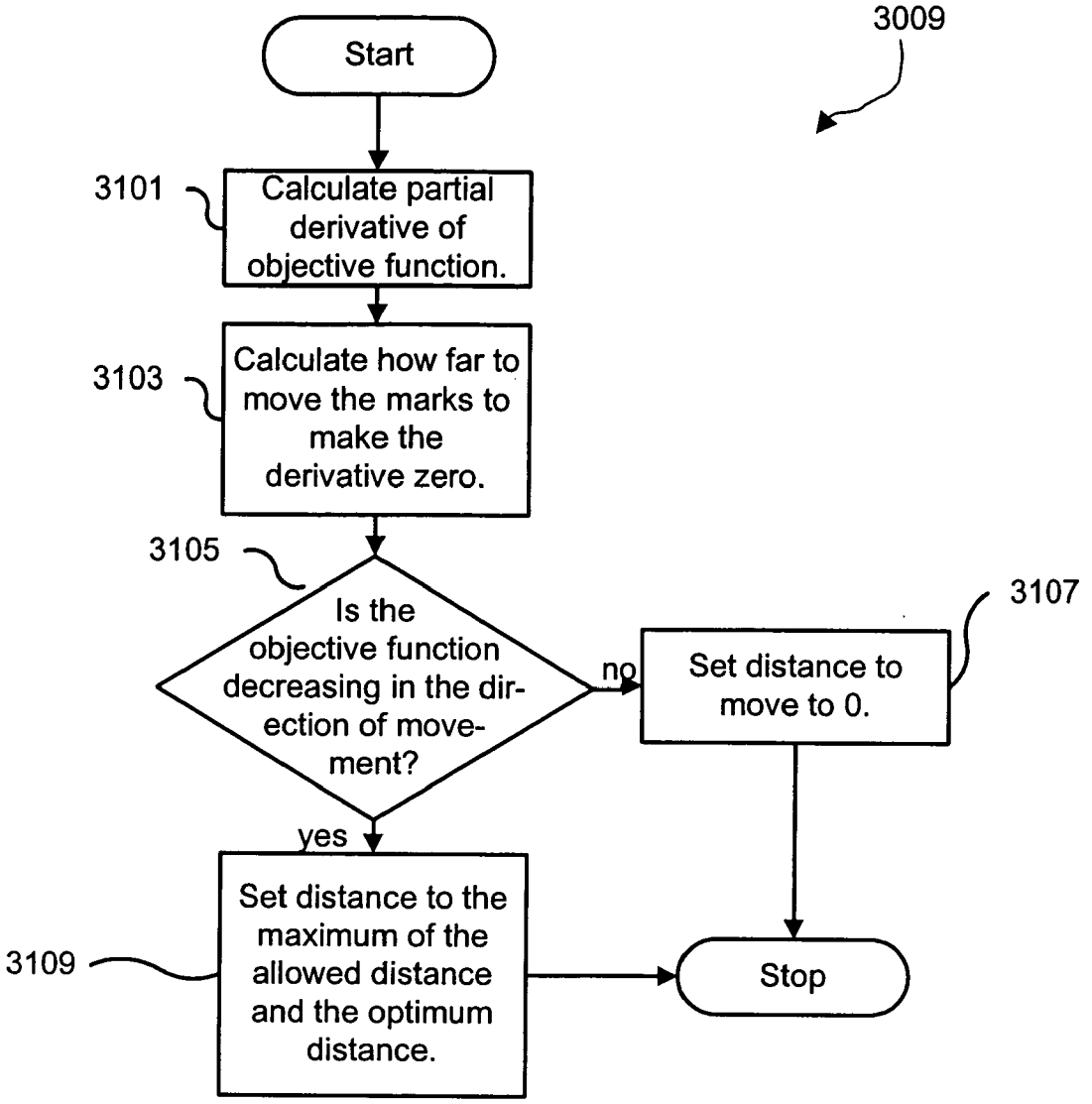

3009
Start
3101
Calculate partial derivative of objective function.
3103
Calculate how far to move the marks to make the derivative zero.
3105
Is the objective function decreasing in the direction of movement?
no
3107
Set distance to move to 0.
yes
3109
Set distance to the maximum of the allowed distance and the optimum distance.
Stop

Fig. 31

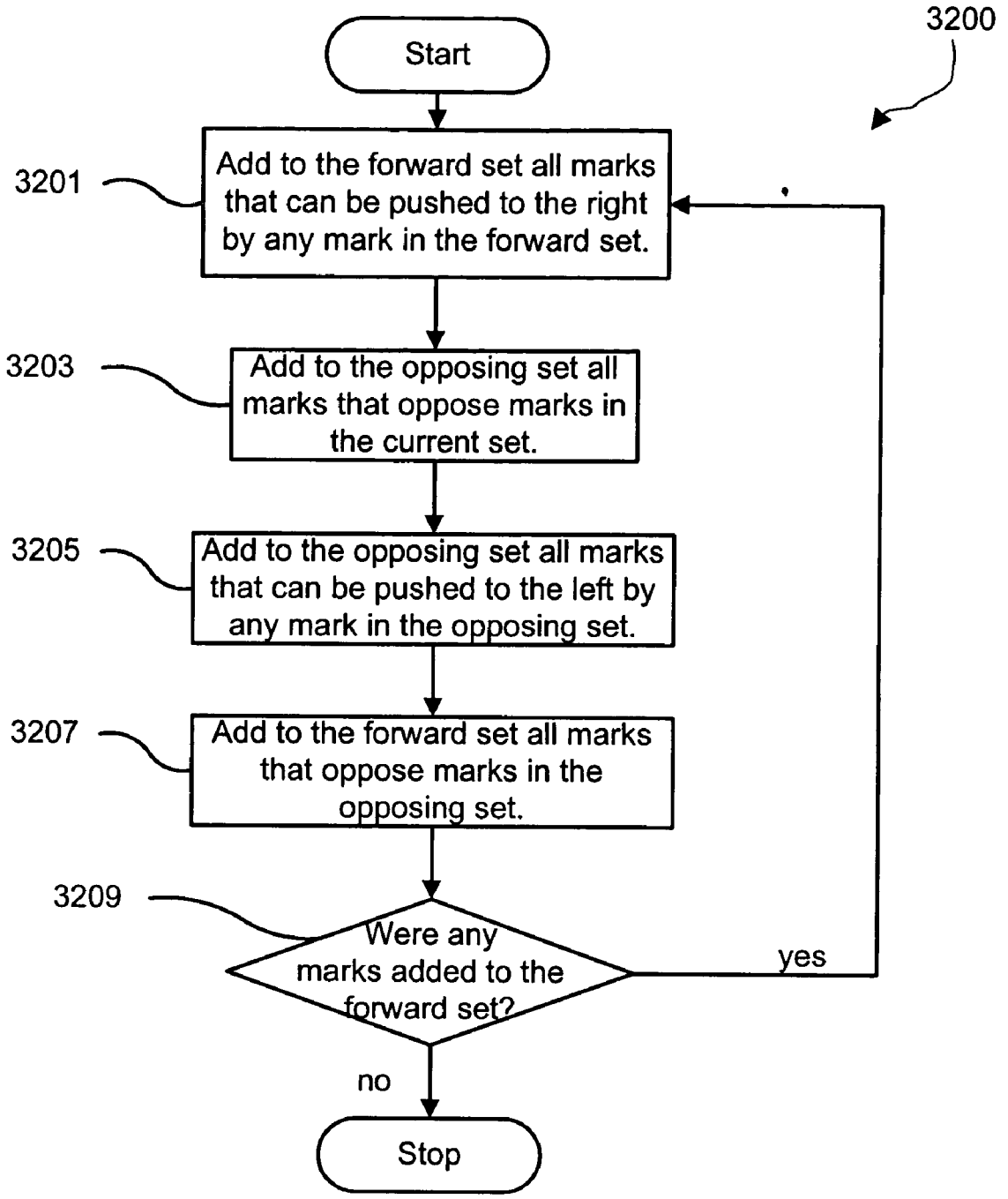

3200
Start
3201
Add to the forward set all marks that can be pushed to the right by any mark in the forward set.
3203
Add to the opposing set all marks that oppose marks in the current set.
3205
Add to the opposing set all marks that can be pushed to the left by any mark in the opposing set.
3207
Add to the forward set all marks that oppose marks in the opposing set.
3209
Were any marks added to the forward set?
yes
no
Stop

Fig. 32

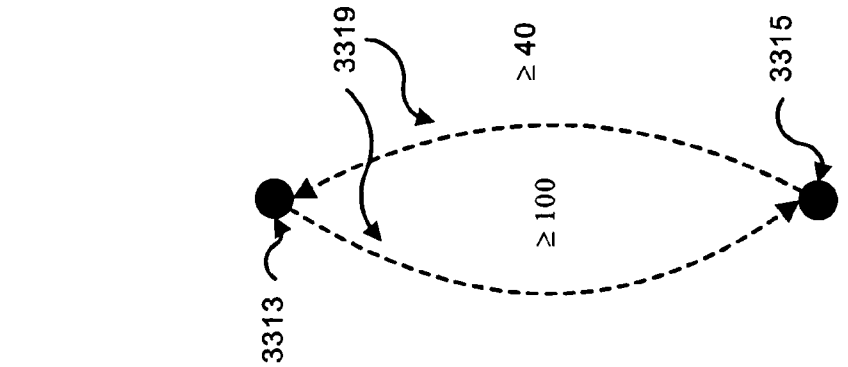


Fig. 33C

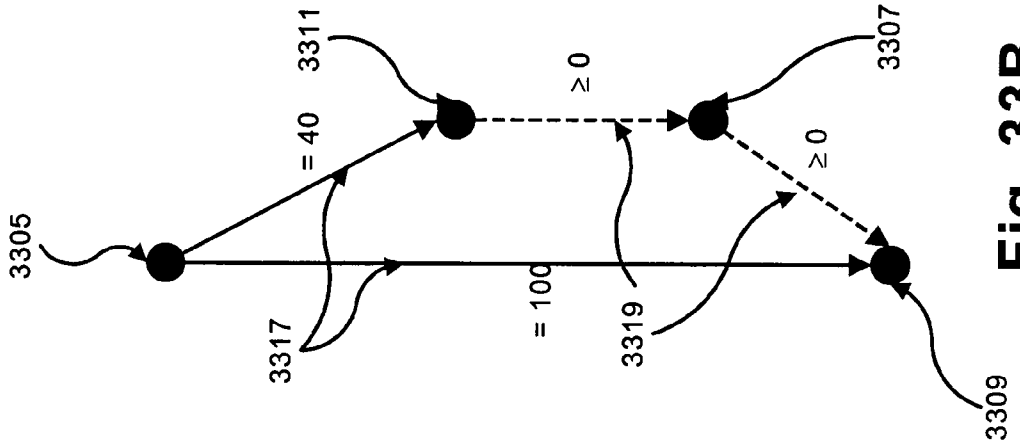


Fig. 33B

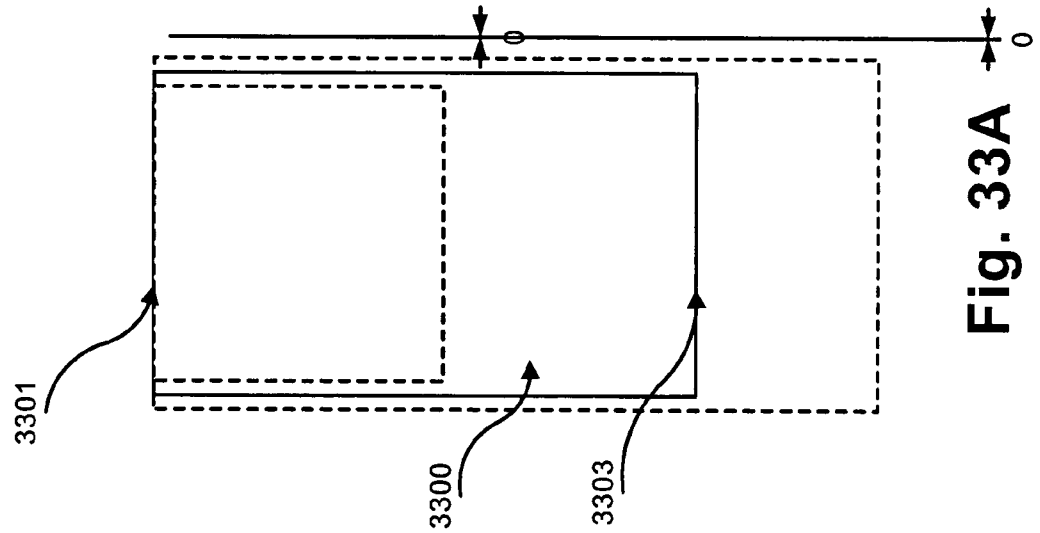


Fig. 33A

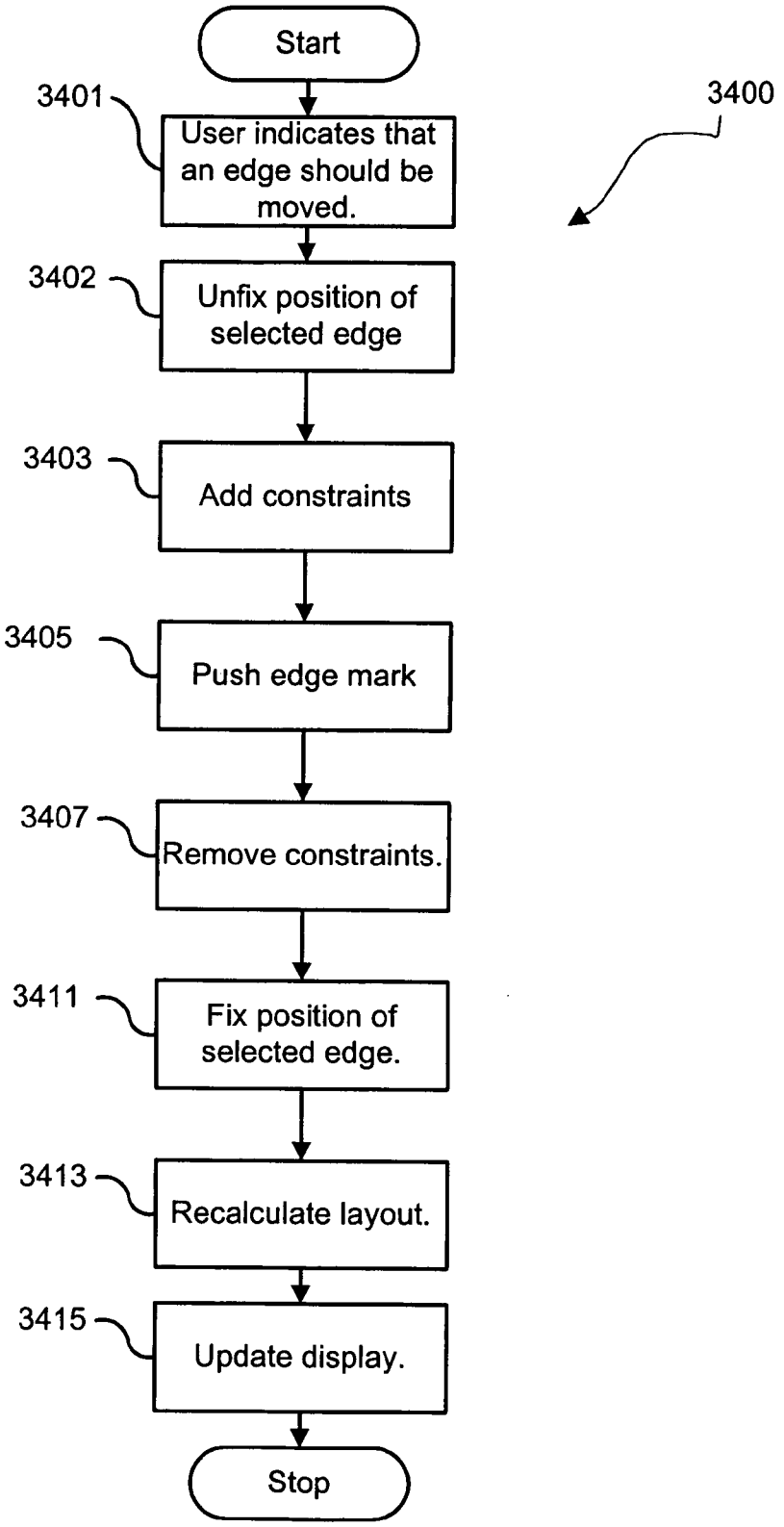

Start
3400
3401
User indicates that an edge should be moved.
3402
Unfix position of selected edge
3403
Add constraints
3405
Push edge mark
3407
Remove constraints.
3411
Fix position of selected edge.
3413
Recalculate layout.
3415
Update display.
Stop

Fig. 34

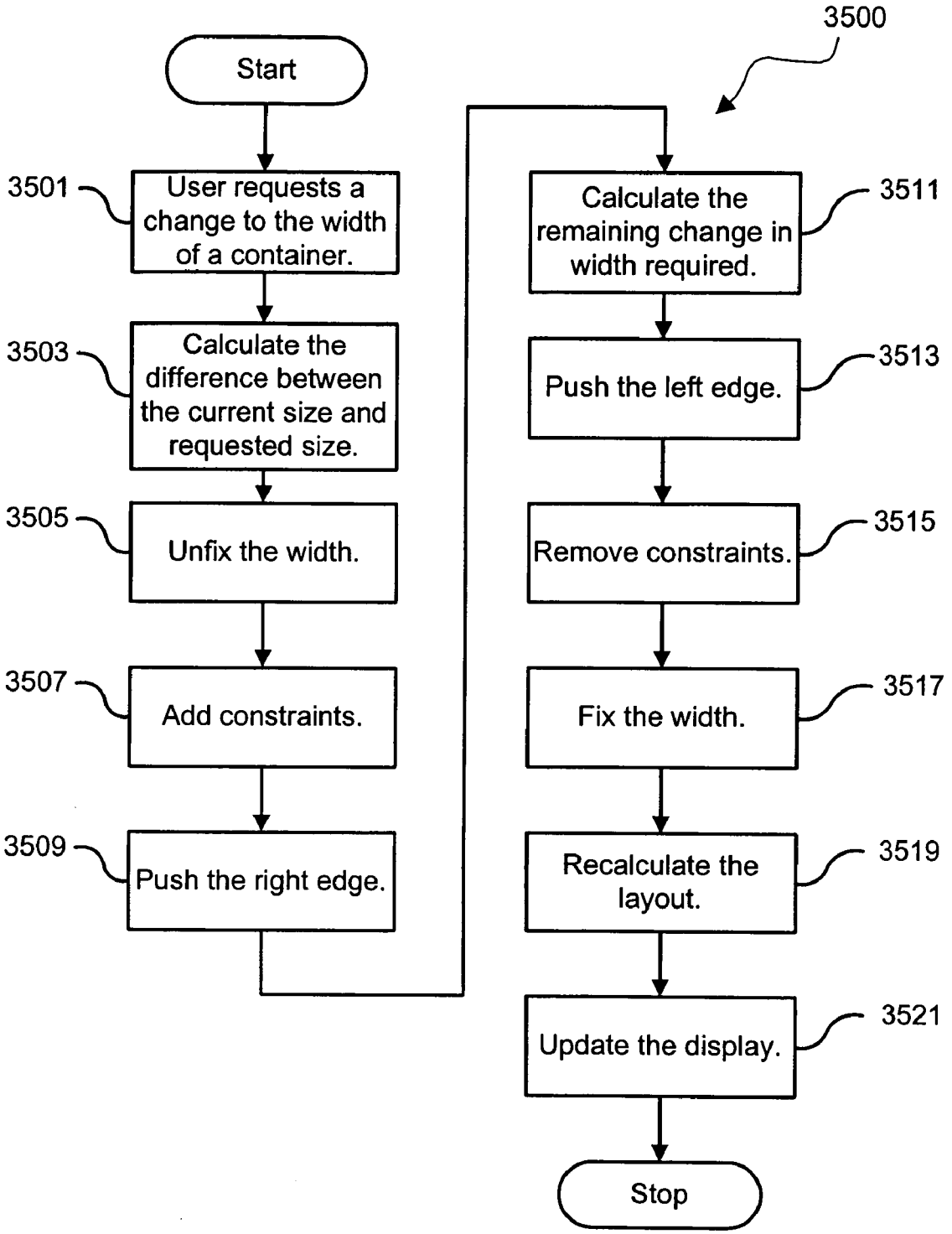

3500
Start
3501
User requests a change to the width of a container.
3503
Calculate the difference between the current size and requested size.
3505
Unfix the width.
3507
Add constraints.
3509
Push the right edge.
Calculate the remaining change in width required.
3511
Push the left edge.
3513
Remove constraints.
3515
Fix the width.
3517
Recalculate the layout.
3519
Update the display.
3521
Stop

Fig. 35

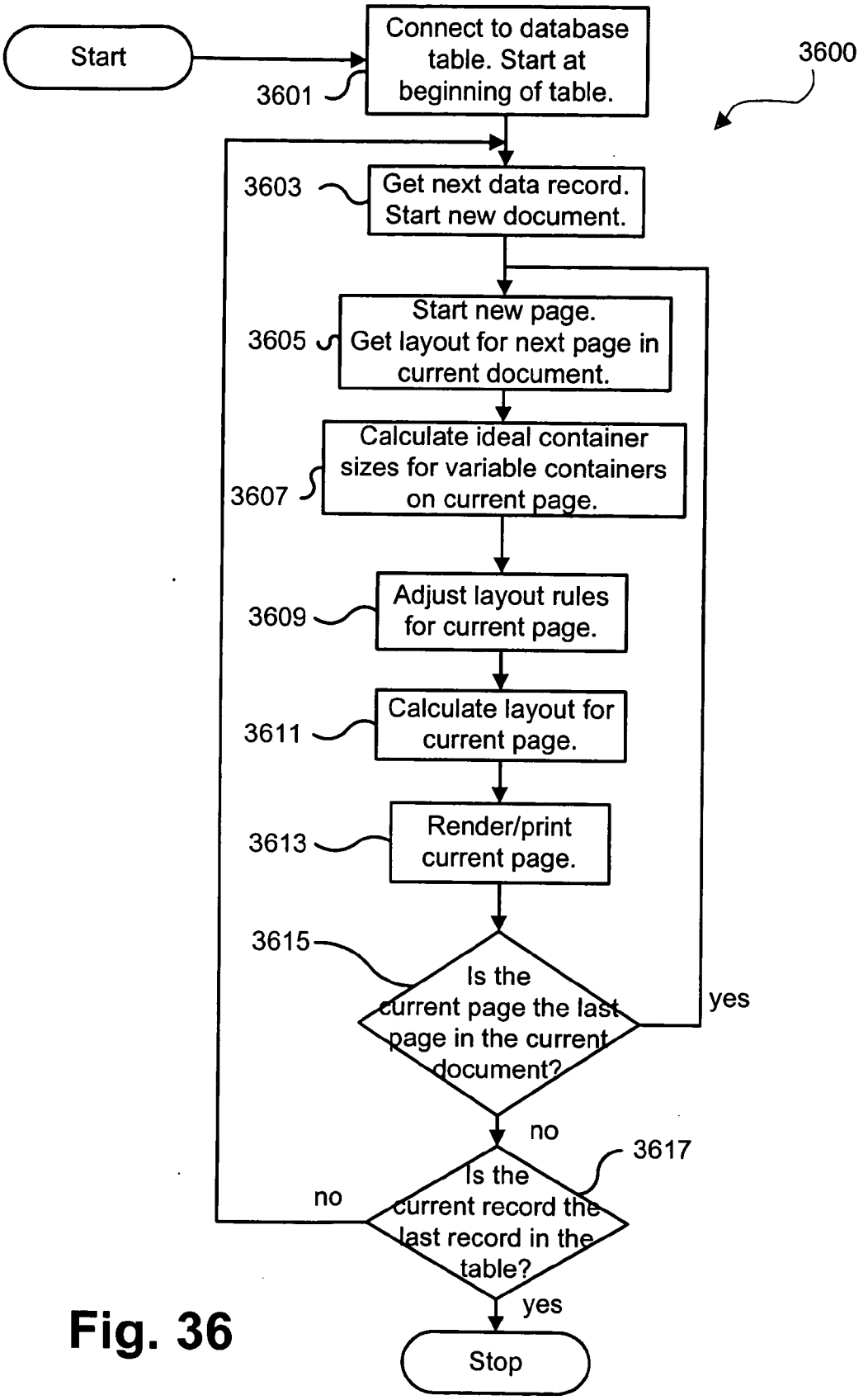

Start
Connect to database table. Start at beginning of table.
3601
3600
3603
Get next data record. Start new document.
3605
Start new page. Get layout for next page in current document.
3607
Calculate ideal container sizes for variable containers on current page.
3609
Adjust layout rules for current page.
3611
Calculate layout for current page.
3613
Render/print current page.
3615
Is the current page the last page in the current document?
yes
no
3617
Is the current record the last record in the table?
no
yes
Stop

Fig. 36

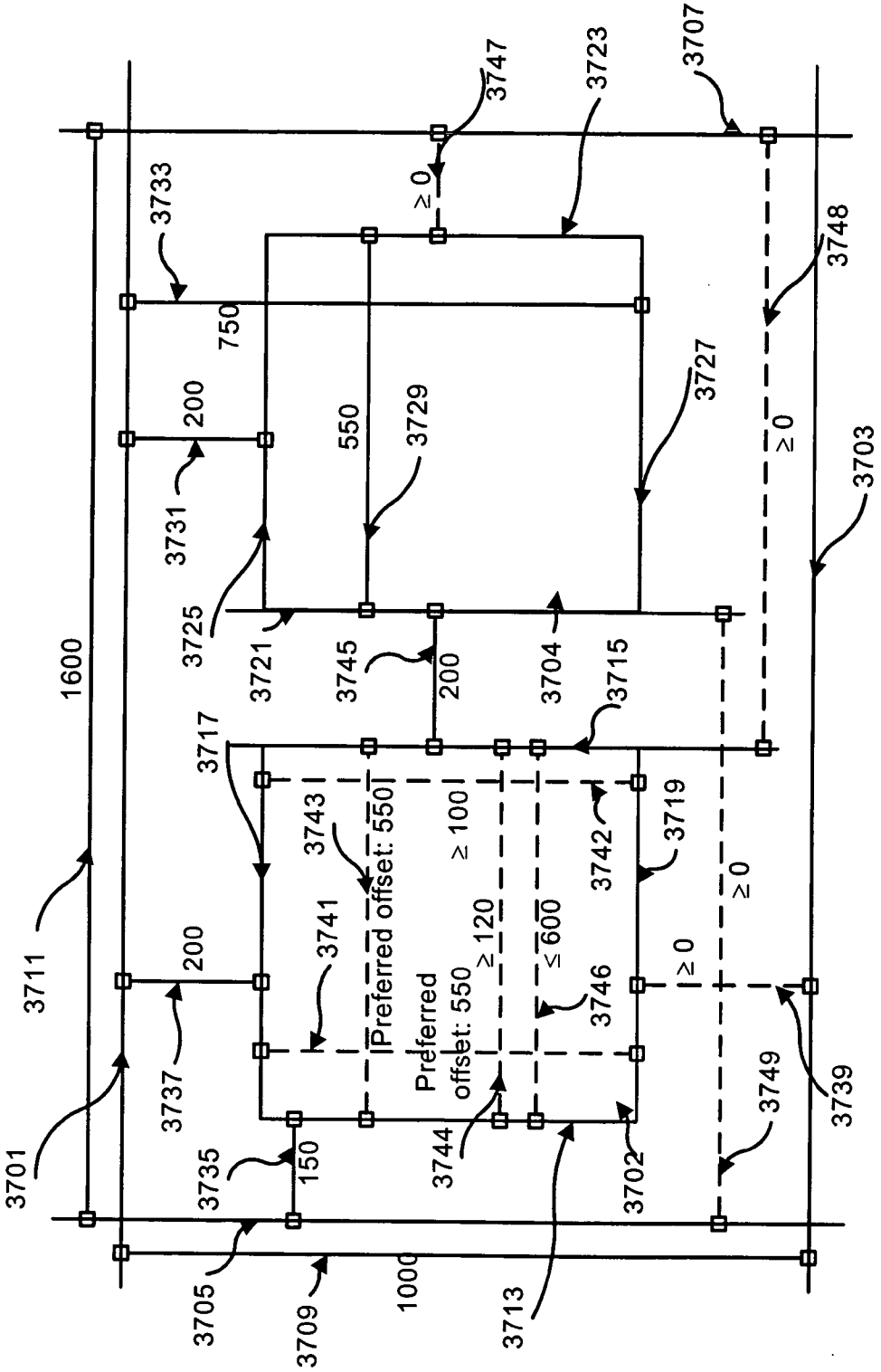

3707
3747
3723
≥ 0
3733
3748
750
3727
200
550
3729
≥ 0
3703
3731
3725
3721
3745
200
3704
3715
1600
3717
3743
Preferred offset: 550
≥ 100
3742
3719
≥ 0
3711
200
3741
≥ 120
≤ 600
≥ 0
3746
Preferred offset: 550
3737
3749
3739
3701
3735
150
3744
3702
3705
3709
1000
3713

Fig. 37A

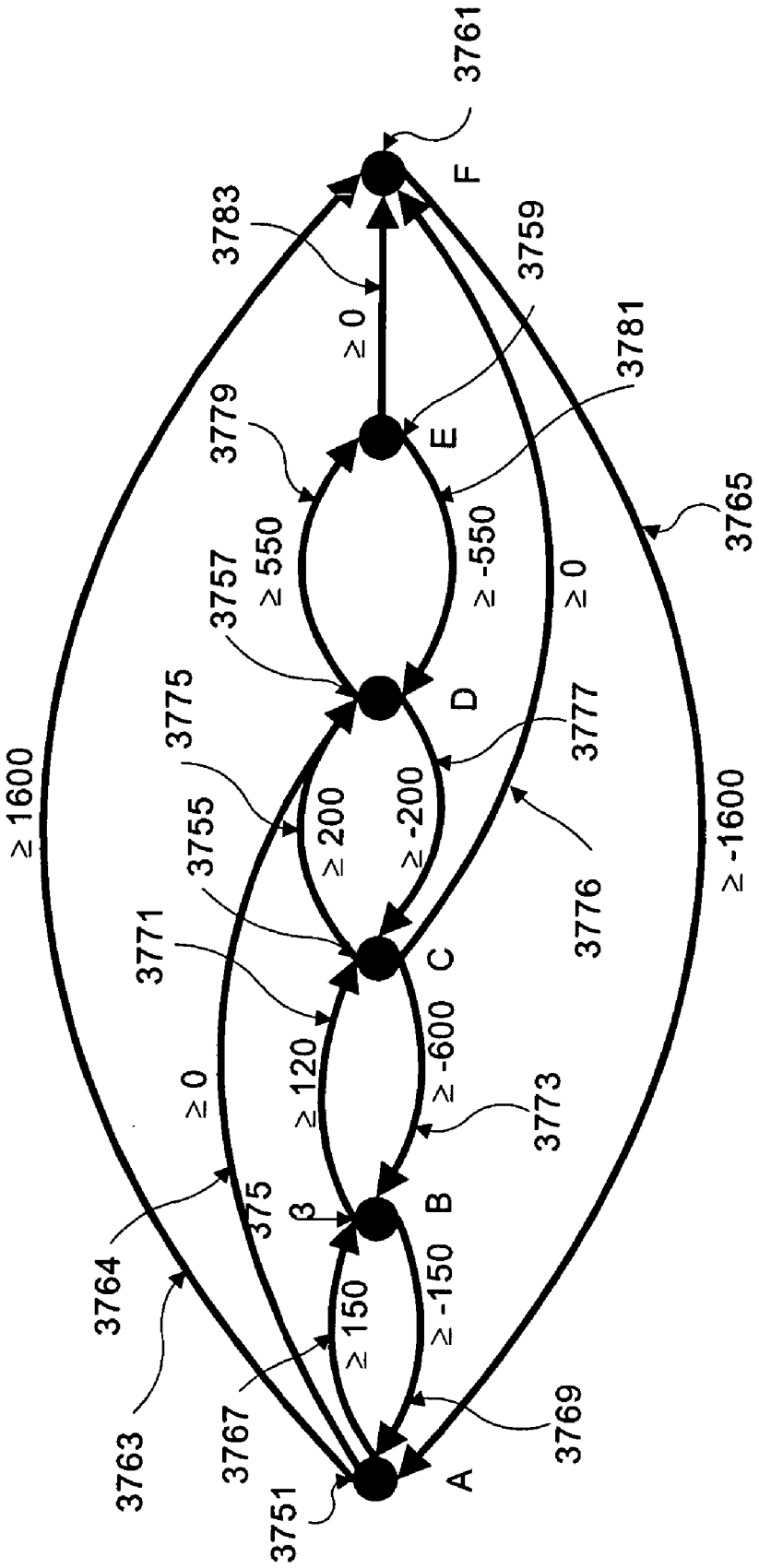

3761
F
3783
3759
≥ 0
3781
3779
E
3765
3757
≥ 550
≥ -550
≥ 0
D
3775
3777
≥ 1600
3755
≥ 200
≥ -200
≥ -1600
3776
3771
C
≥ 0
≥ 120
≥ -600
3773
3764
375
β
B
≥ 150
≥ -150
3763
3767
3769
3751
A

Fig. 37B

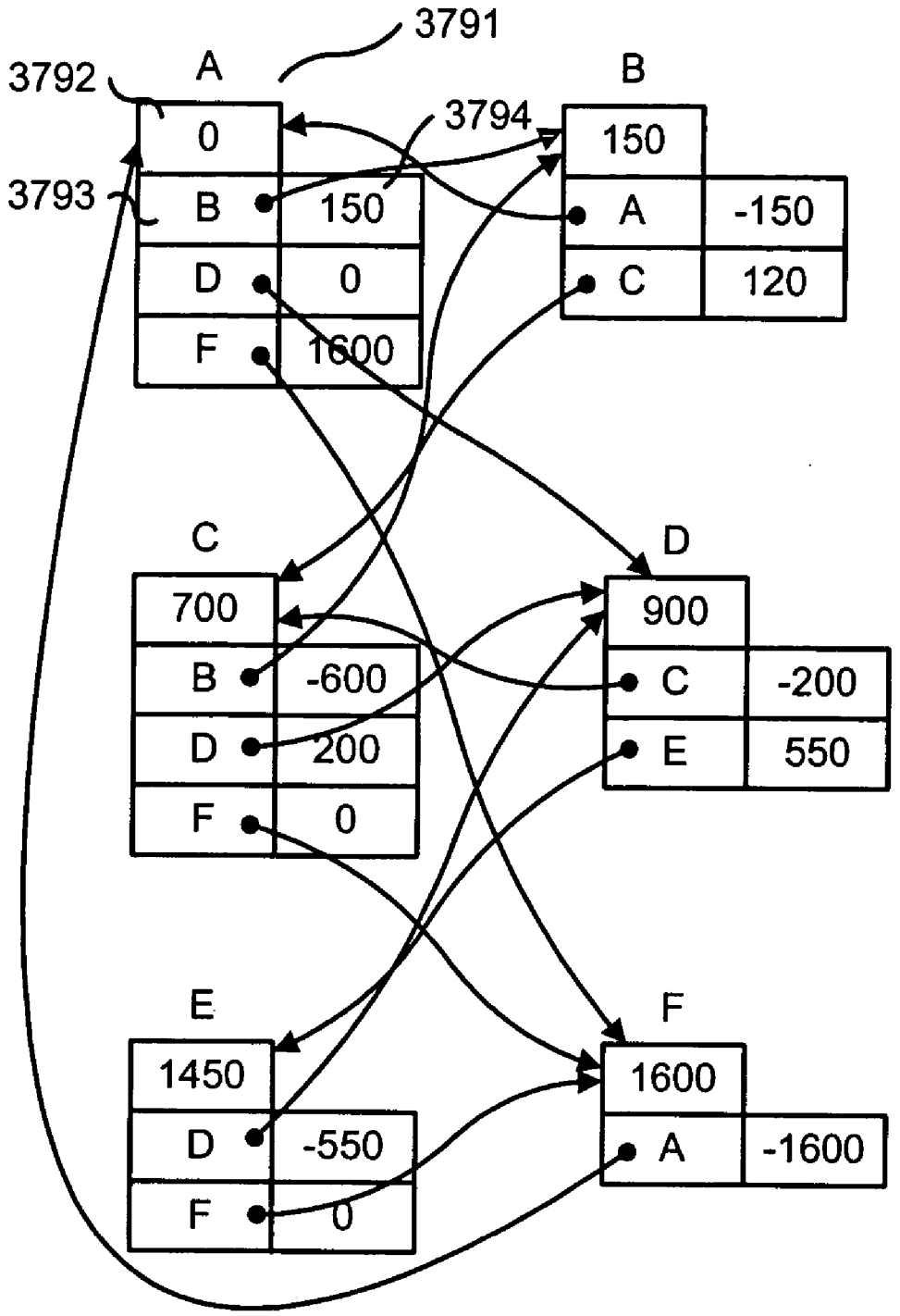

3791
3792
3793
3794
A
0
B
150
D
0
F
1600
B
150
A
-150
C
120
C
700
B
-600
D
200
F
0
D
900
C
-200
E
550
E
1450
D
-550
F
0
F
1600
A
-1600

Fig. 37C

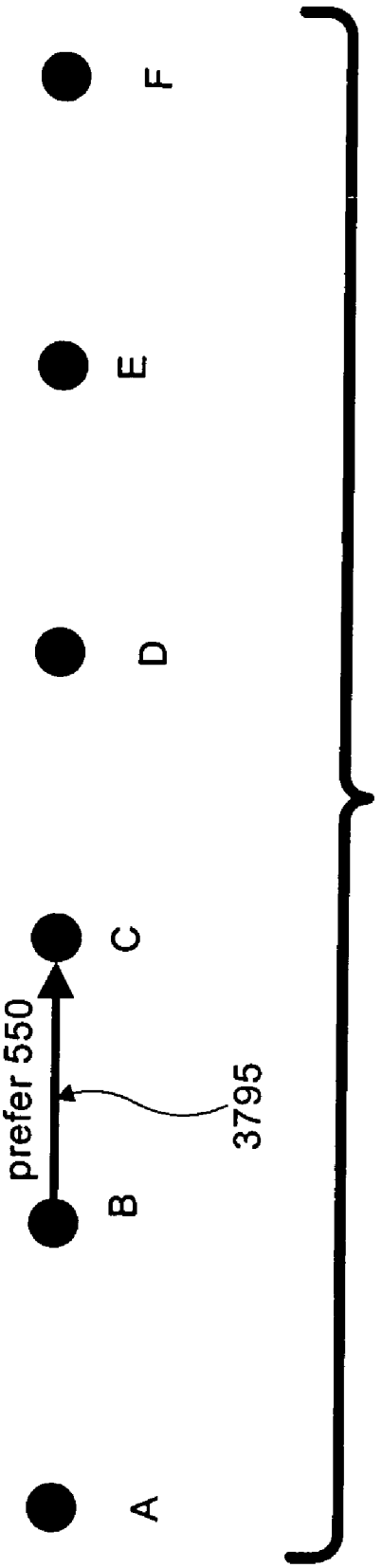


Fig. 37D

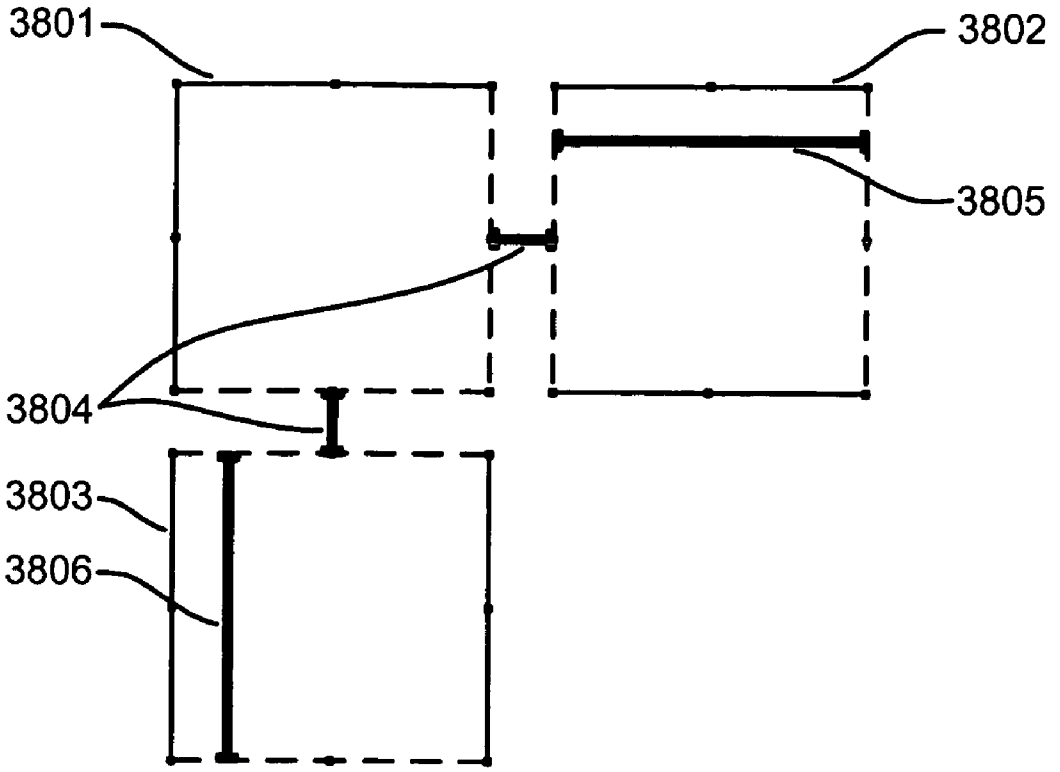


Fig. 38

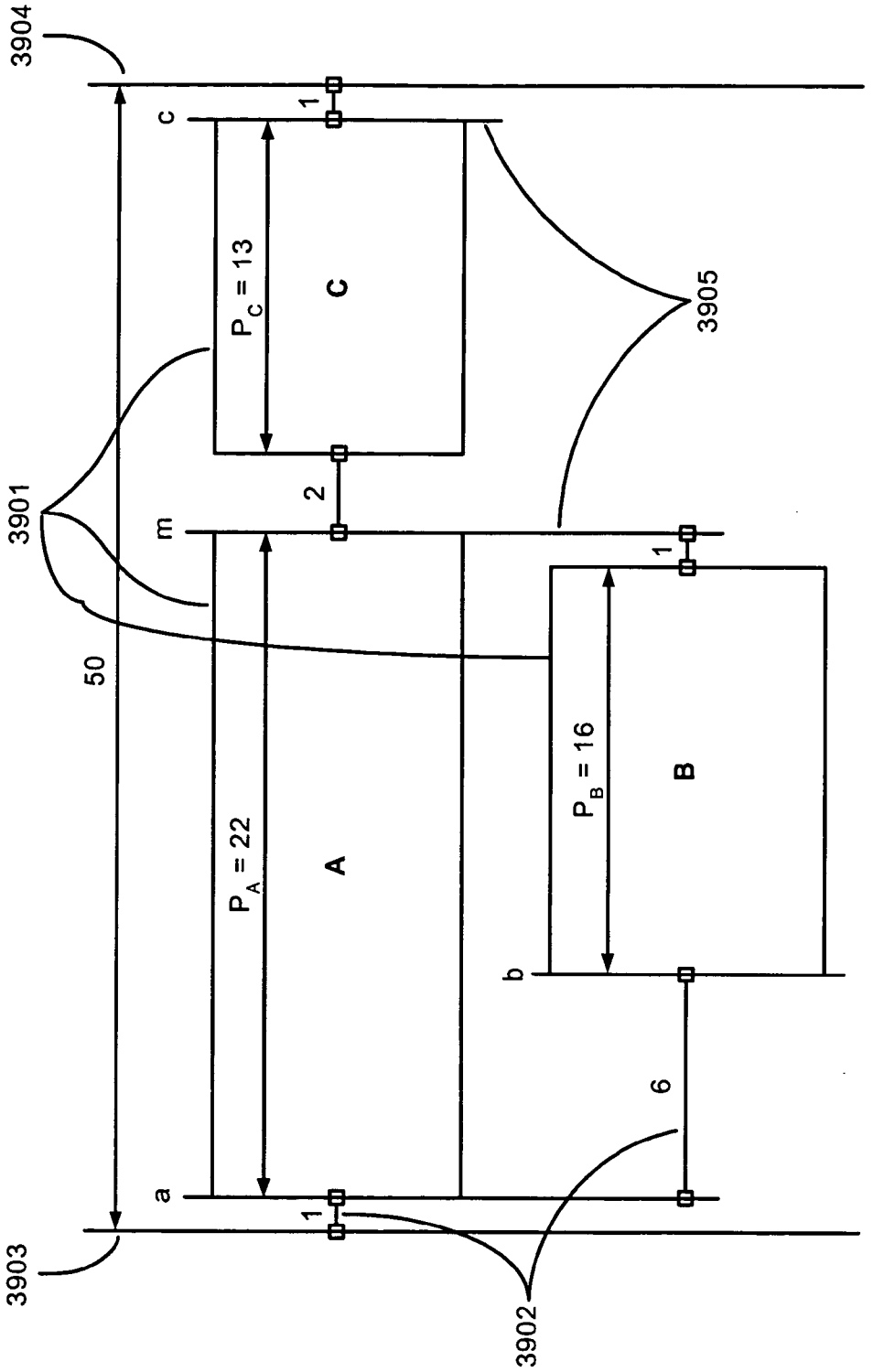


Fig. 39

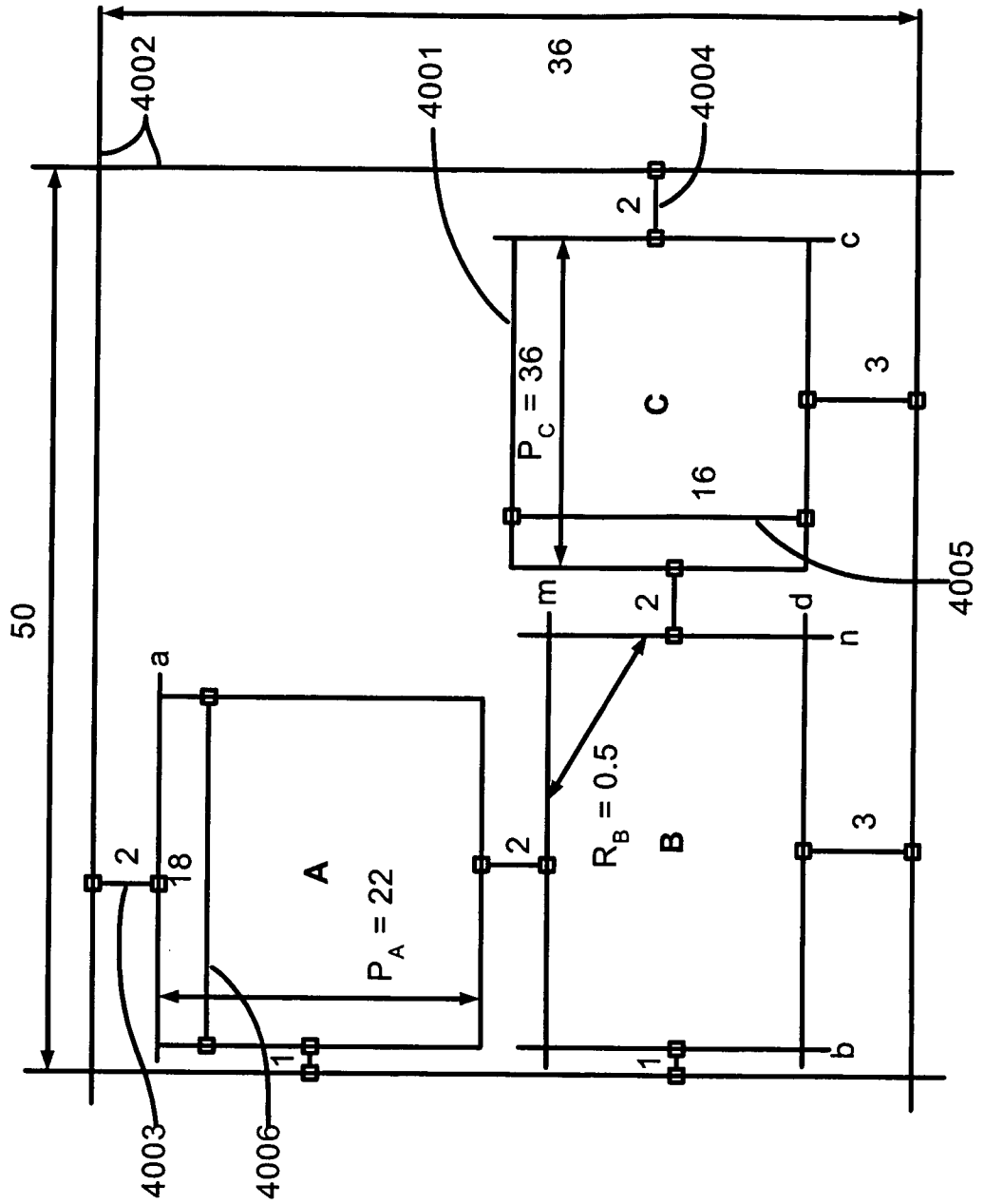

4002
4001
36
4004
2
c
3
$P_C = 36$
C
16
4005
m
2
d
n
50
a
$R_B = 0.5$
B
3
2
18
A
$P_A = 22$
2
1
1
b
4003
4006

Fig. 40A

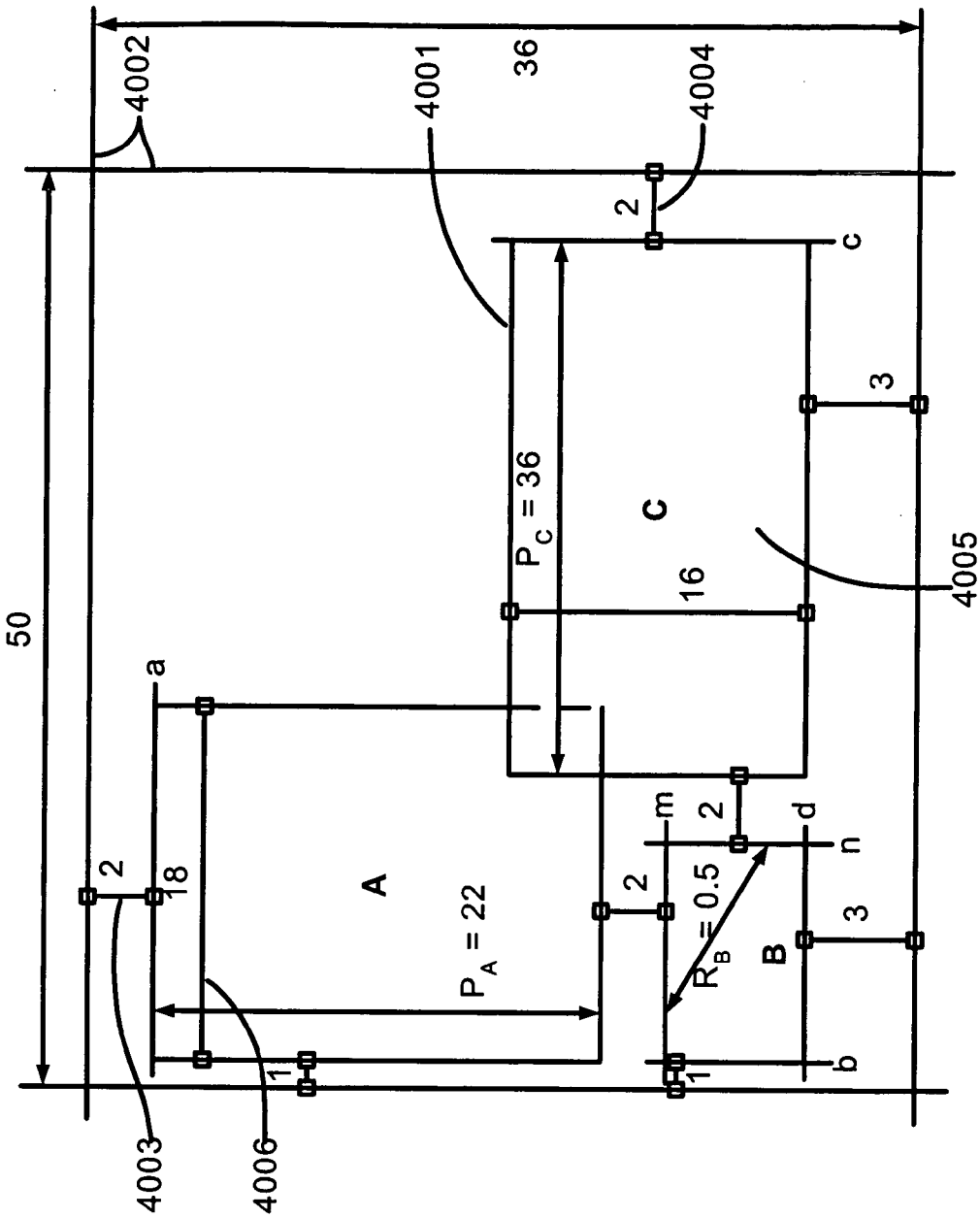
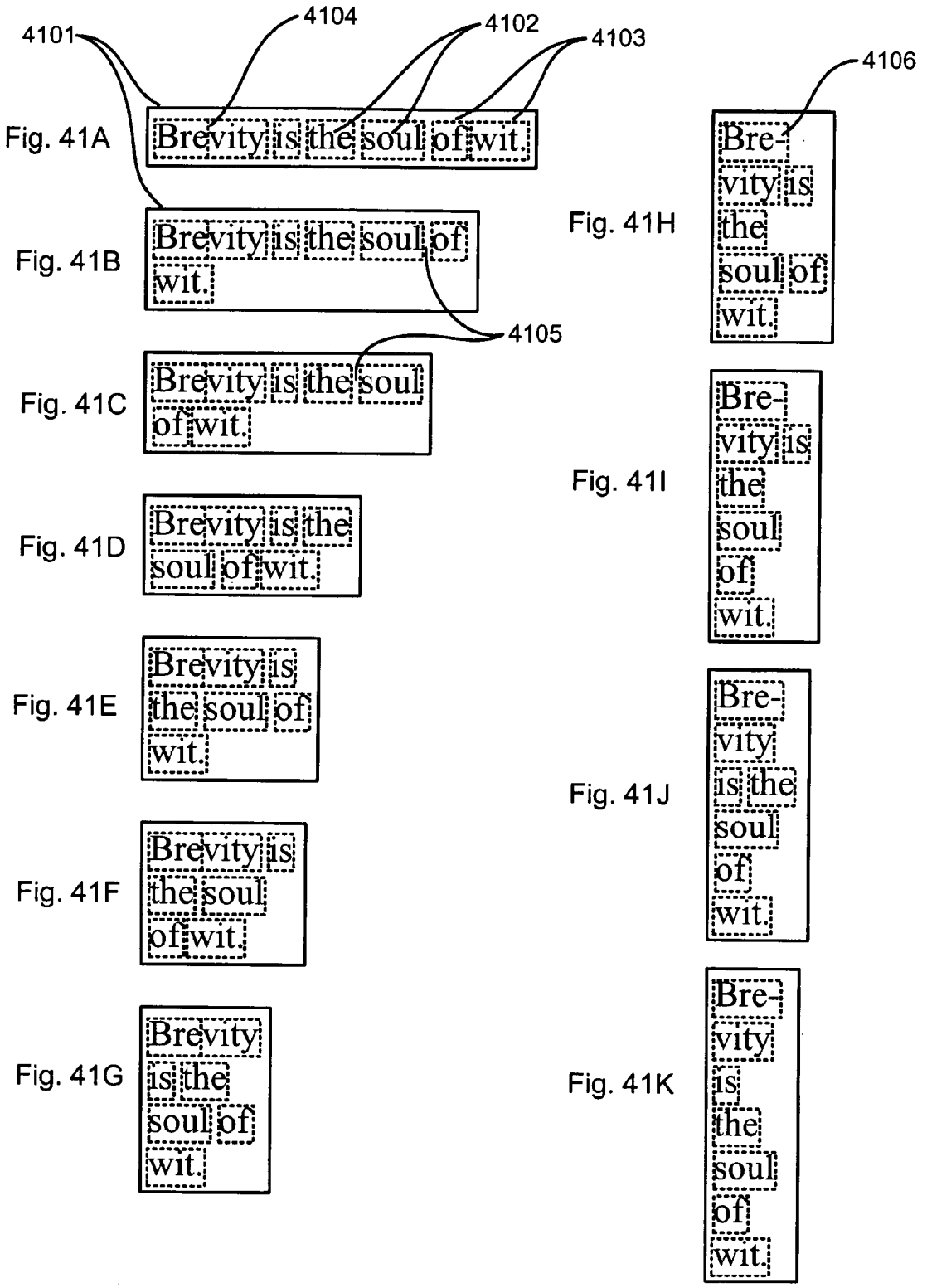

4002
4001
36
4004
50
2
c
3
$P_C = 36$
C
16
4005
a
2
18
A
$P_A = 22$
2
m
2
d
n
$R_B = 0.5$
B
3
1
1
b
4003
4006

Fig. 40B


4101
4104
4102
4103
4106
4105
Fig. 41A
Brevity is the soul of wit.
Fig. 41B
Brevity is the soul of wit.
Fig. 41C
Brevity is the soul of wit.
Fig. 41D
Brevity is the soul of wit.
Fig. 41E
Brevity is the soul of wit.
Fig. 41F
Brevity is the soul of wit.
Fig. 41G
Brevity is the soul of wit.
Fig. 41H
Bre-vity is the soul of wit.
Fig. 41I
Bre-vity is the soul of wit.
Fig. 41J
Bre-vity is the soul of wit.
Fig. 41K
Bre-vity is the soul of wit.

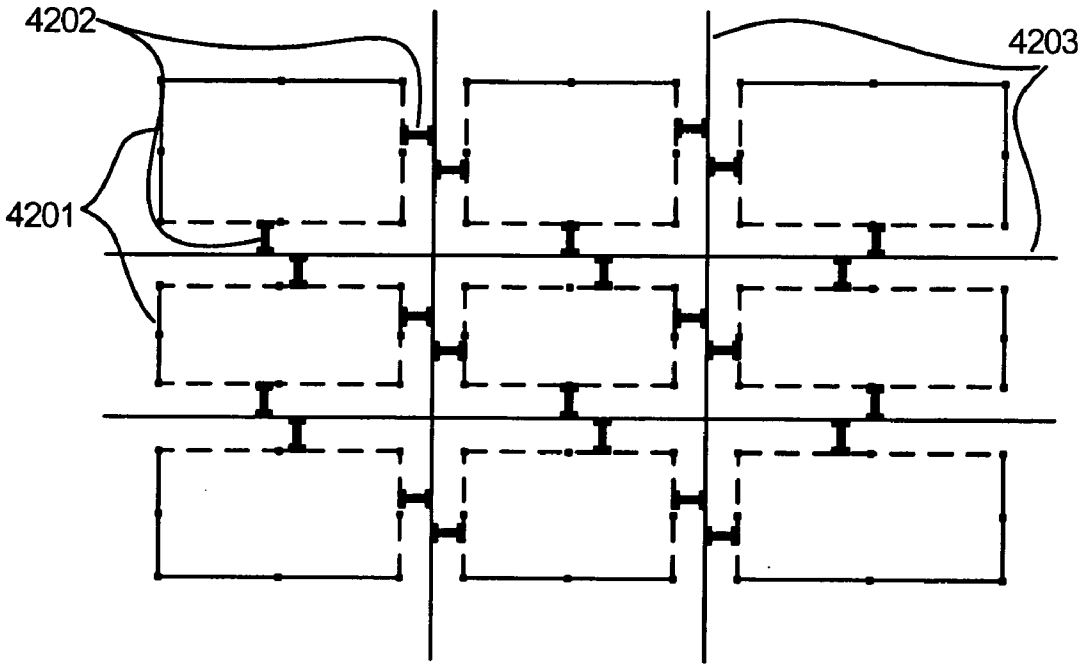


Fig. 42A

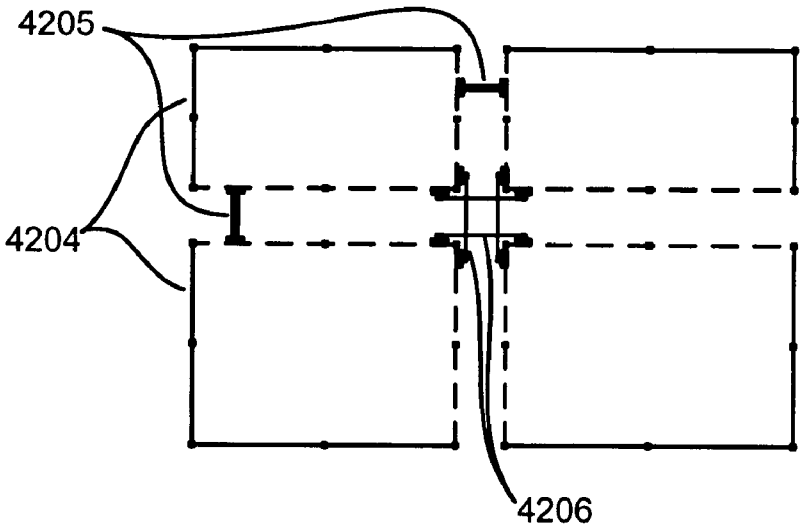


Fig. 42B

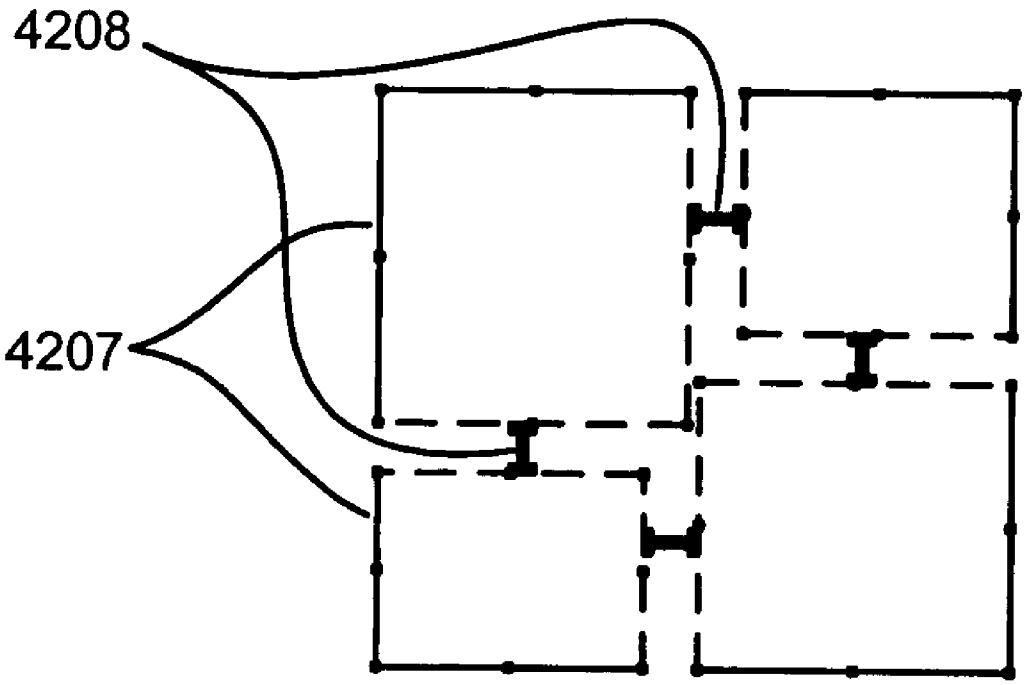


Fig. 42C

SELECTIVE PREVIEW AND PROOFING OF DOCUMENTS OR LAYOUTS CONTAINING VARIABLE DATA

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the right of priority under 35 U.S.C. § 119 based on Australian Patent Application No. 2003905660, filed 15 Oct. 2003, which is incorporated by reference herein in its entirety as if fully set forth herein.

FIELD OF INVENTION

[0002] The present invention relates to software implemented methods and processes for creation, editing, and printing of documents composed of text and graphics and, in particular, to the creation, editing and printing of variable data documents.

BACKGROUND

[0003] Variable Data Printing

[0004] Traditionally, when printing large numbers of documents, the printing processes used have been analogue processes that required physical representations of the documents. These included bromides and/or printing plates that had to be created before printing. This has meant that it was expensive to produce customized documents and large runs of documents typically involved printing multiple copies of exactly the same document.

[0005] Customized documents may be produced using digital printing processes where a physical copy of the document does not have to be prepared before printing. Until recently, digital processes have either been expensive or the results have been of poorer quality than those produced by traditional analogue printing processes.

[0006] In the last five years, however, advances in digital printing have significantly reduced the cost to create high quality customized documents. These advances have lead to the growing popularity of variable data printing. Variable data printing software is becoming available that allows document authors to create not just single documents, but families of related documents, where each document is customized for its intended readers.

[0007] Several problems need to be solved to make high quality customized printing feasible. One problem is the quality of the printed output. Only recently have digital processes been able to approach the resolution of traditional print processes. Another problem is that typically large amounts of data are required to represent a high quality document in digital form, particularly if the document contains a number of high-resolution images. This makes it impractical to electronically transmit large numbers of customized documents to a digital printer via a computer network. A third problem is that customized documents typically require more effort and skill to create and maintain than simple documents. Customized documents are created by inserting variable data into a document template. A document template is a document that has slots for inserting variable data. A document template may include some data that is common to many documents and information defining how to lay out each custom document produced by inserting data into the variable data slots of the template. Authoring a variable data template is more difficult than authoring a simple document because the layout of the pages needs to be defined in a way that can cope with differing sizes of data or missing data items. In addition, the relationship between the template and the data needs to be defined and maintained. As such, database skills are often required in order to be able to create customized documents using variable data printing technology.

[0008] The quality of digital printing hardware has improved to the point where results are comparable to those produced by high-end analogue printing while the cost has come down dramatically. New standards such as PPML allow groups of related documents to be sent to a printer via a network without sending large amounts of repeated data. This reduces the network bandwidth required for variable data printing.

[0009] There is no easy solution to the problem of the complexity of authoring and management of variable data documents. Customized printing has been available in a crude form in word processing software for many years in the form of "mail-merge", but mail merge only supports very crude control over the layout of the individual output documents. The most recent variable data printing software allows the creation of sophisticated, flexible layouts that adjust to the sizes and shapes of data items that may be different in each document, but these applications are still complicated and difficult to use.

[0010] Layout Models

[0011] Typically, a document containing both text and graphics is organized as a collection of items of different types. Items may be text, graphics, or other kinds of abstract objects such as groups, which are collections of items. The layout items typically have a rectangular shape or have a rectangular extent. The rules allowed by each application for defining how to lay out items represent a layout model. In variable data printing applications, the rules must define how the layout is calculated as the sizes of items change.

[0012] Hierarchical Layout Models

[0013] Current variable data printing solutions typically use hierarchical models to define layouts. These models are similar to those used for HTML and XML documents. Examples of such models are the CSS box model and XSL:FO. In such layout models, rectangular items are laid out in a rectangular layout area by stacking them vertically or horizontally inside a layout area.

[0014] In addition to horizontal and vertical stacking, another more general alternative supported by some applications is to allow items to be stacked in vertical columns or horizontal rows, like rows of words on a page. In this form of layout, if there are too many items to fit in a row or column, a new row or column is started and the excess items "wrap" to the next row of column. This is analogous to word wrapping in word processors. This way of laying out items is most useful for applications where the size of the page or layout area may vary widely, such as in web applications. Stacking is less useful for variable data printing applications, because in variable data printing applications, the quality of the layout is usually important, and when the items wrap to the next row or column, the layout often does not look pleasant.

[0015] In hierarchical layout models, complex layouts may be defined by using groups of items. A group is a rectangular layout item that contains other items and is a layout in itself. The items inside a group are laid out inside the bounding rectangle of the group The positions of items in a layout may be controlled by alignment options for example an item in a vertical stack may be left aligned so that the item is always as far to the left of the rectangle that contains the vertical stack as possible. Alignment may be associated with the group so all items in the group will have the same alignment, or each item in the group may have corresponding associated alignment options. Various alignment options are commonly supported including centering, left alignment and right alignment.

[0016] Positions of items may also be controlled by margins associated either with the individual items or associated with the containing layout or group. Margins define the minimum allowed distance between two adjacent items.

[0017] Constraint Based Models

[0018] Current hierarchical layout models are simpler to understand than more general constraint-based models developed previously. Constraint-based models have been used for computer aided design (CAD) applications, user interface construction and window management. In user interface construction applications, the objects to be laid out are widgets such as buttons and input fields. In window management applications, the objects to be laid out are windows that are used to represent views of data as part of a user interface for a computer operating system.

[0019] In user interface construction applications, dynamic layout constraints are used to allow a graphical user interface (GUI) to adapt to different screen resolutions and changes such as the use of different fonts and text sizes. Dynamic layout simplifies the process of building a user interface for multiple platforms.

[0020] In window management applications, the user can apply dynamic constraints to create relationships between windows that are preserved as windows are added or removed, or as windows change size or position.

[0021] CAD applications involve very general geometric constraints, and the layout models are more complex, more difficult to use, and layouts are slower to calculate than document layout models. For example, some constraint solvers used for CAD applications support specifying that two lines are parallel, which cannot be expressed using linear equations.

[0022] Constraint based layout models used for user interface (UI) and window management applications need to be fast enough to be used interactively often if the layout may need to be updated many times per second during graphical editing operations, so the layout method needs to be fast enough to support such operation. These applications typically use a specialized constraint solver to perform layout calculations. The constraint solvers used for these applications typically support linear constraints, expressed as linear equations (i.e. linear equalities), or linear inequalities, or both. Typically, these constraint solvers also have an objective function that defines the quality of a solution. The aim of the constraint solver is to minimize (or maximize) the value of the objective function without violating any of the constraints. If the objective function is also linear, then this type of problem is called a linear program. These types of problems are well-understood optimization problems and there are known algorithms for solving them. Typically, an algorithm called the simplex algorithm is used to solve problems of this type.

[0023] Given a layout problem defined by a set of constraints and an objective function, the problem may be over-constrained, such that there are no solutions. The problem may alternatively be under-constrained, such that there are many solutions, or there may be one solution. To be able to calculate a layout, a layout model needs to ensure that layouts have exactly one solution. One way to achieve this is to report the fact that there are no solutions or too many solutions to the user and allow the user to correct the problem. This is generally not an acceptable solution because it is not easy to present meaningful information to the user about why the problem is over-constrained or under-constrained. If the system is over-constrained, many constraints may be simultaneously inconsistent with each other. If the system is under-constrained, it may not be obvious how to prevent the user from adding inconsistent constraints. This is particularly difficult when the constraints are being edited using a graphical interface.

[0024] One known way to avoid having no solutions is to prioritize constraints into what is called a constraint hierarchy. If there is no solution to the constraints, constraints are ignored in reverse order of priority until a solution is possible.

[0025] A known way to avoid under-constrained problems is to use a non-linear objective function. If a suitable strictly convex function is used, the problem will always have a unique solution. Typically, a quadratic objective function is used, because there are well-known techniques for solving optimization problems with linear constraints and a quadratic objective function. The simplest of these are modifications of the simplex algorithm.

[0026] Another problem with the generation of variable data documents is that of previewing the documents being generated. Word processors and desk top publishing application often use a "print preview" function to assist the user in overall assessment of the work before committing to printing. This can be laborious where a large number of documents need to be previewed.

SUMMARY OF THE INVENTION

[0027] It is an object of the present invention to substantially overcome or at least ameliorate one or more problems associated with variable document printing.

[0028] In accordance with one aspect of the present invention, there is disclosed a method of proofing a plurality of variable data documents each formed from a common layout in which variable data content is placed into one or more containers having locations and sizes within the layout defined by layout rules, the method comprising the steps of:

[0029] (a) assessing a plurality of measures of variation for each container in each document;

[0030] (b) determining the measure of a standard document generated from the common layout;

[0031] (c) comparing the measure of the determined standard document with the measure of the assessed plurality of measures; and

[0032] (d) presenting a document having at least one measure for which the compared result is larger among the assessed plurality of measures based on the result of said comparison.

[0033] In accordance with another aspect of the present invention, there is disclosed a method of creating a layout for a variable data document based upon a template, the method comprising the steps of:

[0034] (a) establishing the template in a graphical user interface;

[0035] (b) setting at least one container in the template to form the layout;

[0036] (c) modifying the layout to thereby generate an exemplary document by placing exemplary content into the at least one container, wherein at least one dimension of the least one container and/or a position of the at least one container in the layout are varied based upon at least a property of the placed content; and

[0037] (d) displaying the exemplary document in said layout via the graphical user interface.

[0038] Other aspects of the present invention, including apparatus and computer programs for performing the methods are also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] At least one embodiment of the present invention will now be described with reference to the drawings in which:

[0040] **FIG. 1A** illustrates a computer system configuration for variable data printing;

[0041] **FIG. 1B** is a schematic block diagram representation of the computer module of **FIG. 1A**;

[0042] **FIG. 2** illustrates an alternative computer system configuration for variable data printing;

[0043] **FIG. 3** illustrates an example of the application main window including menu bars, toolbars, work area and floating palette;

[0044] **FIG. 4** illustrates a screen, tools and icons to show aspects of the present disclosure including exemplary container creation, a first type of struts between containers, anchors and sliders;

[0045] **FIGS. 5A-5D** illustrate a first exemplary container rules;

[0046] **FIGS. 6A-6C** illustrate a third container rules;

[0047] **FIGS. 6D and 6E** are a flowchart depicting the creation of container extents;

[0048] **FIGS. 7A-7B** illustrate a text container with three columns and a method by which both the column and gutter widths can be resized by direct manipulation using a pointing device;

[0049] **FIG. 8** illustrates a screen, tools and icons to show the operation of character size synchronization;

[0050] **FIG. 9** illustrates a screen, tools and icons to show the operation of the automatic application of internal margins;

[0051] **FIG. 10** illustrates the method by which a strut may be added between the edges of two containers in order to describe a distance constraint;

[0052] **FIG. 11** illustrates a screen, tools and icons to show the operation of several features of the user interface including struts between the second exemplary containers;

[0053] **FIG. 12** illustrates a screen to show the operation of the unfixed guides;

[0054] **FIGS. 13 and 14** illustrate a data source selection method;

[0055] **FIG. 15** illustrates a user interface for data source filtering;

[0056] **FIGS. 16 and 17** illustrate a user interface showing methods for navigating through the data source;

[0057] **FIG. 18** illustrates an example of a user interface showing variables of a data source and a method for navigating through the data source;

[0058] **FIG. 19** illustrates a user interface for associating a variable of a data source with a variable document template;

[0059] **FIG. 20** illustrates a user interface for live proofing of the data source content merged with the variable document template;

[0060] **FIGS. 21A and 21B** illustrate a method for calculating an average document, and a most disparate document using the widths and heights of the containers for each document, for use in selective proofing;

[0061] **FIG. 22** is an example layout showing the layout items and constraints that are used as input for the layout method;

[0062] **FIG. 23** shows just the vertical constraints corresponding to the example in **FIG. 22**; and

[0063] **FIG. 24** is a directed graph representing the vertical constraints of **FIG. 23**;

[0064] **FIG. 25** shows the steps involved in performing the push operation.

[0065] **FIG. 26** shows the steps involved in an alternative implementation of the push operation;

[0066] **FIGS. 27A-27F** show an example of the push operation in use, in which **FIGS. 27A and 27B** show the starting position of an example of the push operation, **FIGS. 27C and 27D** show an intermediate stage of an example of the push operation, and **FIGS. 27E and 27F** show the result of an example of the push operation;

[0067] **FIG. 28** shows the high level steps in the graph based layout calculation;

[0068] **FIG. 29** shows the high level steps in an implementation of the graph based layout calculation;

[0069] **FIG. 30A**, shows how the graph based layout calculation reduces the value of an energy function by moving vertical marks;

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[0070] **FIG. 30B** shows another implementation of the graph based layout method that includes handling of fixed center rules;

[0071] **FIG. 31** shows how the distance to move a group of marks in the graph based layout calculation is calculated;

[0072] **FIG. 32** shows the steps involved in calculating the set of forward and opposing sets of marks that are pushed when a set of marks is pushed to the right;

[0073] **FIGS. 33A** to **33**C show how the minimum and maximum height of a container may be specified using different representations of the basic model;

[0074] **FIG. 34** is a flowchart of modifying an edge position of a container in a layout and the interaction with other edges;

[0075] **FIG. 35** is a flowchart of another example of the push operation for editing template documents;

[0076] **FIG. 36** is a flowchart of a method of generating and printing variable data documents;

[0077] **FIGS. 37A** to **37**D illustrate an example layout corresponding to **FIG. 4** and the manner in which the various constraints of the layout may be stored;

[0078] **FIG. 38** illustrates the use of height and width bars to represent container constraints in second container rules;

[0079] **FIG. 39** shows an example use of the layout engine operating in one dimension;

[0080] **FIGS. 40A and 40B** show an example use of the layout engine operating in two dimensions;

[0081] **FIGS. 41A and 41K** depict the laying out of text within a container and how such may be influenced by container shape; and

[0082] **FIGS. 42A and 42C** illustrate approaches for the construction of tables.

DETAILED DESCRIPTION INCLUDING BEST MODE

[0083] 1. Overview

[0084] A variable data document creation and printing system is disclosed which is preferably implemented as a software application. The application allows a plurality of documents to be created that have a similar form yet whose contents may differ. This is achieved by the creation and editing of a document template, and the association of areas on the document template with various data.

[0085] A document template may contain a plurality of containers, each of which is configured to hold content, such as text or image data. Containers can be fixed in position and size, or may vary in dimensions or position from document to document in accordance with user specified rules. The content of these containers can be static or variable (ie. dependent on some data source, such as a database).

[0086] Users may specify various types of data sources from which to obtain data. A data source contains a plurality of data records. The application provides a mechanism for associating the data with containers in the document template.

[0087] The document template and the data from the data source are then "merged" to produce a number of documents, based on the association between the data source and the containers in the document template. Typically, one document is produced for each record, or group of records, in the data source. The documents can then be saved to disk, or printed as required.

[0088] These arrangements afford several independent advantages over the prior art. For example, unlike the prior art, when editing the document template, the user may choose to always see one of the merged documents. This is because the document template and the data are merged dynamically. As a consequence it is possible to see at least what one of the resulting documents will look like while editing the template, unlike the prior art where it is necessary to go to a special preview area to see what a document will look like (instead of the document template).

[0089] The constraints on the containers (which determines which way containers can move and change size) are shown in place, and can be edited in place by clicking on various positions on the containers without having to go to a separate screen or area, unlike the prior art. This simplifies the creation of the document template compared with the prior art.

[0090] 2. Overview of Implementations

[0091] The fundamental implementation is a variable data document creation and printing application comprising at least a user interface and a layout engine. One specific implementation is software executable on a personal computer together with a printer. In another implementation, the application is incorporated as software executable on a processor embedded in a printer or print controller that supports printing of variable data document sets. In yet another implementation, the application is incorporated as software executable on a web server that can serve up documents customized for the viewer. These implementations also incorporate such software when executing upon an appropriate hardware arrangement.

[0092] Variable data printing refers to printing sets of related documents. In non-variable data printing, documents are printed individually and the data for each document is typically sent to the printer separately. In variable data printing, a print job comprising multiple related documents is sent to the printer. Typically, the documents in a variable data print job contain shared elements that occur in multiple documents. This data is typically sent to the printer only once per job instead of being repeated for each document. When a variable data print job is printed, the shared data is inserted into each document. This may require calculation of the layout of the pages of the document as the pages are printed. In this case, the layout method may be part of the software in the printer or print server. More typically, the layout of each document is calculated on a client machine and the layout is sent to the printer as part of the print job, in this case the layout method is performed on the client machine.

[0093] 3. System Description

[0094] **FIG. 1A** illustrates a system **100** for printing variable data documents. The methods described herein may be practiced within a general-purpose computer module **101**, depicted in detail in **FIG. 1B**, wherein the processes

described may be implemented in whole or in part as software, such as a layout editing application program **121** executing within the computer module **101** and being operable over the system **100**. In particular, the layout editing and consequential printing steps may be implemented by instructions in the software that are carried out by the computer **101**. The software may be stored in a computer readable medium, including the storage devices described below, for example. The software is loaded into the computer from the computer readable medium, and then executed by the computer **101**. A computer readable medium having such software or computer program recorded on it is a computer program product. The use of the computer program product in the computer preferably results in an advantageous apparatus for document layout editing and variable document printing.

[**0095**] The computer module **101** couples to input devices such as a keyboard **132** and a pointing device such as a mouse **133**, and to output devices including a display device **144** and optionally a local printer **145**. An input/output interface **138** enables coupling the computer module **101** to other computing devices of the system **100** via a network connection **107**. The network connection **107** is typically a Local Area Network (LAN) or a Wide Area Network (WAN).

[**0096**] The computer module **101** typically includes at least one processor unit **135**, a memory unit **136**, for example formed from semiconductor random access memory (RAM) and read only memory (ROM), input/output (I/O) interfaces including a video interface **137**, and an I/O interface **143** for the keyboard **132** and mouse **133**. A storage device **139** is provided and typically includes a hard disk drive **140** and a floppy disk drive **141**. A magnetic tape drive (not illustrated) may also be used. A CD-ROM drive **142** is typically provided as a non-volatile source of data. The computer module **101** utilizes an operating system, such as GNU/Linux or Microsoft Windows, and the components **135** to **143** of the computer module **101**, typically communicate via an interconnected bus **134** according to the operating system and in a manner which results in a conventional mode of operation of the computer system formed thereby, known to those in the relevant art. Examples of computers on which the described arrangements can be practiced include IBM-PC's and compatibles, Sun Sparcstations or alike computer systems evolved therefrom.

[**0097**] Typically the layout editing application program **121** is resident on the hard disk drive **140** and read and controlled in its execution by the processor **135**. Intermediate storage of the program **121** and any data fetched from the network **1020** may be accomplished using the semiconductor memory **136**, possibly in concert with the hard disk drive **140**. In some instances, the application program **121** may be supplied to the user encoded on a CD-ROM or floppy disk and read via the corresponding drive **142** or **141**, or alternatively may be read by the user from the network connection**107**. Still further, the software can also be loaded into the computer module **101** from other suitably sized computer readable media including magnetic tape, a ROM or integrated circuit, a magneto-optical disk, a radio or infra-red transmission channel between the computer module **101** and another device, a computer readable card such as a PCMCIA card, and the Internet and Intranets including email transmissions and information recorded on websites and the like. The foregoing is merely exemplary of relevant computer readable media. Other computer readable media may be used.

[**0098**] The application **121**, whilst named for layout editing, also operates to perform variable data printing (VDP) and includes two software components. The first of these components is a layout engine **105**, this being a software component for calculating the positions of rectangles and lines with given constraints and sizes within a rectangular area. Secondly, a user interface **103** component provides a mechanism for allowing the user to construct a document template, and to associate regions in the document template with data sources. The user interface **103** and layout engine **105** communicate via a communications channel **123**. A data source for document generation is typically a database **119** that is hosted on a database server **117**, generally formed by another computer upon which is running a database application. The host computer **101** communicates with the database server **117** by means of the network connection **107**. The variable data printing application **121** generates document templates that can be saved to the host computer **101** or to a file server **115**, generally formed by another computer. The variable data printing application **121** also produces documents, formed by the document template merged with data. These documents can be saved to the local file system on the host computer **101**, saved on the file server **115** or sent to the print server **109** or printer **113** directly for printing. The print server **109** is a computer which provides a network capability to printers that cannot be networked directly. The print server **109** and the printer **113** are connected via a typical communications channel **111**.

[**0099**] **FIG. 2** is similar to **FIG. 1** except for the addition of the engine server **227** containing a separate version **225** of the layout engine **105**. The engine server **227** is another typical computer. Document templates stored on the file server **115** are able to be combined with data stored in the database **119** to generate documents for printing or other purposes by the layout engine **225**. Such operation may be requested via the user interface **103**, or just to request a specific record to be printed.

[**0100**] 4. Main Window

[**0101**] Referring to **FIG. 3**, the user interface **103** includes a graphical user interface formed by an application window **301** which, when operating, is displayed on the video display **144**. The window **301** features a menu bar **302**, a toolbar area **303** that in some implementations may be detached and moved to various locations on the screen, a work area **306**, an optional floating palette **311** and a cursor/pointer device **313**, whose location is typically associated with a position or movement of the mouse **133**.

[**0102**] The menu bar **302** has a number of menu items **304** which, when activated, expand into a hierarchy of menu options as is common in the present art.

[**0103**] The toolbar **303** has a number of tool buttons or widgets **305**, each of which may be hidden or shown depending on the particular mode of the application.

[**0104**] Optional rulers **308** may be used to indicate the position of the pointer, pages, lines, margins guides, containers or other objects in the work area. The rulers **308** may show numerical indication of the units used, for example inches, millimeters or pixels.

[0105] The floating palette **311** can be used to access additional functions such as the variable data library. The palette **311** has its own window controls **312** allowing it to be moved, resized or closed. The palette **311** may optionally remain in front of the work area at all times, or may be hidden behind other objects. The palette **311** may be constrained to appear only within the extents of the application window **301**, or can be allowed to appear partially or wholly outside of the application window **301**.

[0106] Referring to **FIG. 4**, the toolbar area **303** is shown having at least the following user selectable iconic "buttons":

[0107] Selection Tool button **403**: used to select, move, scale, resize and lock/unlock container edges. Containers can also be multiple selected by dragging a selection box around containers or holding down the CTRL key whilst selecting containers.

[0108] Image Container Tool button **405**: used to create containers for holding static or variable images.

[0109] Text Container Tool button **404**: used to create containers for holding static or variable text.

[0110] Strut tool button **406**: used to control the distance between containers.

[0111] These buttons can be implemented with context sensitive tool tips, as is well known in the art.

[0112] 5. Document Template

[0113] The work area **306** is used to view and edit the design of a document template. This allows the user to design the printed appearance of the documents under preparation and understand how each merged document varies based on the amount and size of variable data being merged with the document template.

[0114] If an external data source has been linked to the template, variable text and images are displayed in their containers so that users can preview the current document as they work.

[0115] Visual clues that describe the structure of a document and the behavior of its variable data containers are displayed whenever the user rolls the cursor over or selects a container.

[0116] The work area **306** features a scroll bar **307**, optional rulers **308** and the document template **309**. The document template **309** can show a plurality of pages.

[0117] The page size for a given document template is specified by the user as is well known in the art. The actual number of pages in each document may vary depending on the variable data. Additional pages may be automatically created to display data if all doesn't fit onto one page.

[0118] Within each page boundary is an optional page margin **310** indicating the maximum extents of printable objects on the page.

[0119] Also illustrated in **FIG. 4** is an example of a plurality of objects that could appear on a page of document template **309**, those being: a multiplicity of containers **407**, **408**, featuring optional anchor icon **409**, unfixed edges **410**, strut **412** and sliders **413**.

[0120] 6. Containers

[0121] A container is a space within a document template into which static or dynamic content such as text, images, and other containers or objects may be placed. Containers may be moved, scaled and reshaped by manipulation of the container as depicted in the user interface using a pointing device **313**, and control via the mouse **133**.

[0122] More precisely, a container has a collection of settings, visual appearances, and interaction and editing behaviors. The following are all part of the definition of a container:

[0123] A container may have static and/or dynamic content. Dynamic content is dynamic in the sense that it comes from a data source and may differ for different documents. Dynamic content is not intended to include animated or content otherwise changing with time, as such are not adapted for printing. Similarly static content will appear the same in all documents produced using this container, although due to the action of dynamic content, static content may be placed differently for each document.

[0124] A container may have cosmetic features, such as a background color, a border, and text settings such as fonts and styles, which apply to content of the container.

[0125] A container may be merged with data from a data source when producing a document. The cosmetic features are typically visible in printed output, as are any static content. Dynamic content will result in the appearance of particular data from the data source. This representation of a container could be printed, for example, or displayed on the screen **144**, or both.

[0126] A container may also have a user interface, for example an interactive graphical user interface for editing and viewing settings of the container. The interface elements typically appear on the screen **144** but not in printed documents. The user interface **103** may display some of the cosmetic features of the container, such as background color or font, and may also add features to allow editing and viewing of the settings of the container. Examples of special-purpose user interface features are borders or corner icons for displaying and changing the size or position of a container interactively, or overlaid numbers, lines, icons or text to indicate the behaviour of the container when the container is merged with data from a data source.

[0127] One aspect of the present disclosure is a set of new direct manipulation techniques, and methods of display involving the graphical user interface component of a container.

[0128] 6.1 Container Constraints

[0129] According to the present disclosure, a container may have several constraints which control how associated content may be displayed in each document. These constraints, together with a means of associating static and dynamic content with the container, are the primary method by which a user controls the generation of multiple documents from a single document template. An example of a

constraint is "this container's content may be a maximum of four inches tall". Another constraint might be "the left edge of this container's content must appear in the same horizontal location in each document". Described herein is a set of methods for displaying and editing such constraints using a graphical user interface.

[0130] Content placeholders that specify the locations of static content, such as an image having some defined location on a page, are well known in the digital printing arts. In the following discussion it may be assumed that containers may have a position and size and these may be displayed and edited in manners similar to those known in the art. Instead, the present discussion focuses on the display and editing methods particular to variable data printing.

[0131] Containers allow a user to specify the size and position of content in documents. Since several documents may be generated from a single document template, a container must have a user interface for specifying and displaying a multitude of possibilities and constraints.

[0132] The edges of a container define a virtual boundary within which associated content will appear in documents. Thus, in this patent specification, discussing the left edge of a container may be equivalent to discussing the left-most edge of where the associated content can be displayed in any documents produced. Similarly, discussing the height of a container may be understood as discussing the constraint on the height of the associated content in any documents produced. Where this patent specification discusses the edge or size of a container with reference to the user interface **103**, this distinction will be made clear.

[0133] In the following discussion, the term 'fixed' defines that some value used to control the appearance of content is the same in all documents:

[0134] If a width of a container is fixed, this means the width allowed for associated content will be the same in all documents.

[0135] If a height of a container is fixed, this means the height allowed for associated contents will be the same in all documents.

[0136] If a distance constraint is fixed, then the specified distance is constant for all documents.

[0137] If a left or right edge of a container is fixed, this means the horizontal position of that edge is the same for all documents relative to the page, but the height or vertical position of the container may change. For example, if the left edge of a container is fixed, associated content can appear near the top the page in one document and near the bottom of the page in another, but the left edge will have the same horizontal position in all cases.

[0138] If a top or bottom edge of a container is fixed, this means the vertical position of the edge is the same for all documents relative to the page, but its width or horizontal position of the container may change.

[0139] The vertical axis of a container is an imaginary vertical line positioned half-way between and parallel to the left and right edges of the container. If the vertical axis of a container is fixed, then the average of the horizontal positions of the left and right edges of the container will be the same for all documents. With this constraint, a container's width may vary, thus both the left and right edges may be farther from or closer to the vertical axis in different documents, but the axis remains in the same horizontal position for all documents. The container's height and vertical position are unaffected by this constraint.

[0140] Similarly, if the horizontal axis is fixed, this constrains where the top and bottom edges of a container are vertically positioned, although the height is unaffected by this constraint.

[0141] If both the horizontal and vertical axes are fixed, this means the central point of a container is fixed, but its width and height are unaffected by this constraint.

[0142] If a corner of a container, mid-point of an edge of the container, or the central point of the container is fixed, this mean that point appears in the same location in all documents and in the same location relative to the container. For example, if the top-left corner of a container is fixed, this means the top-left point of where its contents may be placed is the same for all documents.

[0143] A vertical edge or axis may be fixed relative to the left hand edge of the page, or the right, or the left page margin, or the right page margin, or some other horizontal position. Similarly, a horizontal edge or axis may be fixed relative to the top or bottom edges or margins of the page, or some other vertical position. These refinements of the term 'fixed' are only significant if page sizes may vary between documents, since if the page size is the same for all documents these possibilities yield no difference in the documents produced.

[0144] The opposite of 'fixed' is 'unfixed' which means the edge, axis, corner, mid-point, or distance constraint may vary between documents, but might not necessarily do so in a particular set of documents. For example, there may be other external constraints, which actually prevent the position of an edge from varying, but the fact that the edge position could vary if those external constraints didn't apply means that the edge is still labeled unfixed.

[0145] 6.2 Container States

[0146] The 'edge state' of a container is defined as a set of 8 properties that can be 'fixed' or 'unfixed' as described above: left edge, right edge, vertical axis, top edge, bottom edge, horizontal axis, width and height. The edge state may not fully constrain the position of an edge, since edges may also be affected by other constraints, such as minimum or maximum container size settings, or the positions of other containers. Thus 'edge state' refers to only a portion of the full set of states, which a container may have.

[0147] Edge state is significant in most implementations, because the graphical user interface for a container is derived in part from mapping edge states onto graphical representations, and from mapping direct manipulation of edges and container representations onto adjustments to edge state.

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[0148] Preferably, a container's full state includes more than the edge state. Containers may have minimum and maximum settings for width and height, which further control edge positions. Internal margins control where associated content may be displayed, which may in turn affect where container edges can be placed. Text font, style, size and alignment settings as well as image cropping, scaling, etc may also be a part of the state of a container, and may affect content positions, sizes and appearances. Cosmetic settings such as background and border colors, border line weights, styles and so on are also part of each container's state. Whilst such aspects might not affect the positions of content in documents, they will affect the appearance.

[0149] In some implementations, edge state includes the above-mentioned 8 properties that can be either fixed or unfixed. Page sizes cannot vary, so the term 'fixed' here has no further qualifiers. These 8 properties lead to 2^8 distinct edge states, which is 256 possibilities.

[0150] Not all these 256 edge states need be used. For example, consider the state where the left edge of a container is fixed, the vertical axis is fixed and the right edge is unfixed. Since the vertical axis is fixed, the distance from the left edge to the vertical axis must equal the distance from the right edge to the vertical axis for all documents. Since the left edge is also fixed, the distance of the left edge from the vertical axis is constant for all documents, which implies the right edge is also fixed.

[0151] Certain implementations model a subset of edge states, each of which exhibits unique behavior. The edge state described above is not used in all implementations since its behavior is identical to several other states. An alternate implementation might employ such states and represent them in the user interface, as a means of modeling and editing whether edges are fixed, instead of modeling unique container behaviors.

[0152] One specific implementation uses 36 container states, formed as the product of 6 unique horizontal constraints and 6 unique vertical constraints.

[0153] The horizontal constraints on a container are:

[0154] 1. the left and right edges, the vertical axis and the width are unfixed;

[0155] 2. the left edge only is fixed;

[0156] 3. the right edge only is fixed;

[0157] 4. both the left and right edges are fixed;

[0158] 5. the vertical axis only is fixed; and

[0159] 6. the width is fixed, but the left and right edges and vertical axis are unfixed.

[0160] The vertical constraints on a container are:

[0161] 1. the top and bottom edges, the horizontal axis and the height are unfixed;

[0162] 2. the top edge only is fixed;

[0163] 3. the bottom edge only is fixed;

[0164] 4. both the top and bottom edges are fixed;

[0165] 5. the horizontal axis only is fixed;

[0166] 6. the height is fixed, but the top and bottom edges and horizontal axis are unfixed.

[0167] If the term 'fixed' has qualifiers, for example if each edge or axis could be fixed relative to either the left or right edge of the page, this would lead to more than 36 unique edge states.

[0168] Note that the constraint in the above list labeled "Both the left and right edges are fixed" has the same behavior as "The left and right edges, the vertical axis and width are all fixed", and "The left edge and vertical axis are fixed", and indeed several other similar constraints. The simpler, symmetrical constraint is generally preferred since an implementation which uses visual cues to represent various notions of 'fixed' can use fewer such cues if edge states employ fewer 'fixed' constraints, which may in turn produce less visual clutter than would otherwise be the case.

[0169] One aspect of the present disclosure associates edge states with graphical representations and editing methods for containers, as described below.

[0170] 6.3 Displaying and Editing a Container

[0171] 6.3.1 Method for Creating New Containers

[0172] Two classes of container are described: text containers and image containers. A text container holds text and/or embedded images. An image container only holds images.

[0173] Referring to **FIG. 4**, new text containers and image containers can be created in the document template **309** by clicking on the text container tool **404** or image container tool **405** respectively, using the mouse **133**, and then dragging a rectangle in the template **309**.

[0174] Alternatively a container may be created simply by clicking in the document template **309** after activating the appropriate tool **404**, **405**. Either a container of a default size is inserted, or a dialog box or other prompt is provided for entering the dimensions of the new container. Some containers may be automatically created and placed according to some pre-defined or calculated scheme. Other alternatives may be devised.

[0175] 6.3.2 Method for Displaying Containers

[0176] Preferably, each of the 36 edge states described earlier is mapped onto a graphical representation. There may be fewer than 36 graphical representations, since some edge states may share a representation in some circumstances.

[0177] **FIGS. 5A-5D** illustrate first exemplary edge rules for a container.

[0178] The application **121** draws edges as solid lines (see item **503**) or dashed lines (see **504**) and also features anchors (drawn on or near an edge and composed of lines, shapes and/or icons as shown by **506**, **507**, **509**), handles (control points drawn on or near an edge or shape to allow it to be moved or modified, see **502**), sliders (short parallel lines drawn on either side of an edge, see **FIG. 4**, the items labeled **413**), growth icons (see **505**), and colors, to represent edge state.

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[0179] The rules for the container display method of **FIGS. 5A-5D** are, in order:

[0180] 1. for each fixed edge, draw that edge solid;

[0181] 2. if the width is fixed, draw the left and right edges solid;

[0182] 3. if the height is fixed, draw the top and bottom edges solid;

[0183] 4. axes are not drawn;

[0184] 5. all edges not yet drawn are drawn dashed with a growth icon drawn near each edge;

[0185] 6. for each pair of perpendicular edges and/or axes, at their intersection draw an anchor if both are fixed;

[0186] 7. for each fixed edge, draw a slider at the centre of the edge if no anchors have been drawn anywhere on that edge; and

[0187] 8. for each pair of perpendicular edges and/or axes, at their intersection draw, a handle if no anchor or slider has been drawn in that location.

[0188] Rules 1, 2 and 3 ensure lines are drawn solid if they are fixed or constrained. Rule 5 ensures unfixed edges are drawn dashed. Rules 6, 7 and 8 ensure that fixed points display anchors, some fixed edges display sliders and others display handles.

[0189] In the above, edges need only be drawn once so if a rule causes an edge to be drawn then later rules will not cause that edge to be drawn again. Icons may be drawn differently or omitted if it is convenient to do so, for example if the container is very small and the icons would overlap each other or obscure other features of the representation.

[0190] The exact location where unfixed edges are drawn may depend on the content of the container content. As described later, 'live proofing' is used, which means content is merged with the document template and may be visible in the user interface. An alternate implementation can use the container's content area averaged over all documents, or some other means of deciding where unfixed edges should be placed in the user interface.

[0191] These representations of containers provide a graphical method of displaying container edge states. The interpretation of the representations is as follows:

[0192] A dashed line means the position of that edge in documents depends on the content of the container. In **FIG. 4**, such an edge is labeled **410**.

[0193] A solid line means the edge is constrained, either because the edge is fixed (such as edges **414**) or the width or height of the container is fixed (both are fixed in container **408**).

[0194] An anchor means the edges and/or axes which intersect that anchor are fixed. Hence, the anchor point will appear in the same horizontal and vertical position in all documents. An anchor is therefore, by definition, fixed. Icon **409** in **FIG. 4** is an example of an anchor icon which indicates the intersecting edges **414** are fixed.

[0195] A slider means the associated edge is fixed but the container may be located in many positions 'sliding lengthways' along the edge. For example, in **FIG. 4**, the sliders **413** indicate the contents of container **408** may appear in a document to the left or right of the position seen in that particular diagram.

[0196] Some or all of these icons or edges may be drawn or not drawn depending on which tool or which containers are selected, highlighted or otherwise activated. Container edges and icons are, in general, not drawn in a printed document since they are an aid to the design of a document template.

[0197] Settings such as minimum and maximum width and height can be displayed in a secondary dialog window.

[0198] In **FIG. 5A**, container **501** is unfixed in both width and height. Fixed edges **503** are represented by solid lines. Unfixed edges **504** are represented by broken lines. Growth icons **505** are additional or alternative indicators that the adjacent edges **504** are unfixed.

[0199] In **FIG. 5B**, container **501** is unfixed in both width and height. Anchor icon **506** additionally or alternatively indicates that both edges **503** intersecting at the icon are fixed.

[0200] In **FIG. 5C**, container **501** is unfixed in both width and height, with expansion or contraction of the container occurring equally around the center point as indicated by optional anchor icon **507**.

[0201] In **FIG. 5D**, container **501** is unfixed in both width and height, except that the top edge **508** is fixed. Anchor icon **509** indicates that the top edge **508**, in the center of which the icon is located, is fixed, and also indicates that the container's left and right edges expand or contract around a central axis line drawn vertically through the icon (the vertical axis).

[0202] 6.3.3 Method for In-Place Editing of Container Properties By clicking on or in the proximity of any edge **503** or **504** with the mouse **133** and pointing device **313**, the edge **503**/**504** is swapped between the fixed and unfixed state, and the graphical representation in the user interface **301** is updated accordingly.

[0203] Control points **502** may be dragged using the combination of the mouse **133** and the pointing device **133**, causing the corresponding edge or edges to follow the position of the control point **502**. On releasing the control point **502** from selection with the mouse **133**/pointer **313**, a fixed edge remains in the position to which it has been dragged, assuming there are no external constraints causing the new position to be invalid, while an unfixed edge will return to its calculated position, which is determined by factors such as the size and shape of the content inside the container and any other constraints that may apply to the container or edge. See later for a full description of the algorithms used to determine the position of unfixed edges and containers.

[0204] Control points located at the centre of an unfixed edge or at the intersection of two unfixed edges may be fixed or may be not shown at all, and control points located on either end of one unfixed edge may be restricted to movement in the direction parallel to the edge.

[0205] Additionally, anchors may be added to a vertex or edge of a container by clicking with the pointing device **133** in the proximity of that vertex or edge, or on the control point located at that vertex, or in the centre of the edge. Anchors may also be removed by clicking in the proximity of the anchor icon, or alternatively by selecting the anchor then activating a menu item, button or other control in the interface.

[0206] Adding an anchor in this way will result in the edge, edges, axis or axes intersecting the anchor becoming fixed.

[0207] It is desirable for containers to have at least one point that is fixed, unless otherwise externally constrained, since without this requirement it would be possible to create containers for which the horizontal or vertical position is poorly defined. For example, the content of a container which has no fixed edges or axes could logically appear anywhere on a page if the container has no external constraints otherwise operative. This would make it difficult for the user to predict where content of such a container would appear in documents. Consequently, this possibility is prevented some implementations by disallowing transitions that would place containers into such a poorly defined state.

[0208] A container may have a fixed width or height without having corresponding edges fixed, providing the container has an external constraint, as described above. For example, a container could have a fixed width despite having its left and right edges unfixed, provided its horizontal position of the container can be ascertained by some horizontal constraint. Such external constraints are discussed below and are called "struts".

[0209] Provided an external constraint strut is attached to a container, the width or height can be fixed by clicking on edges in a manner similar to that described above for fixing edges. In this circumstance, clicking on or near an unfixed left or right edge will fix the width of the container if there is a horizontal strut connected to the container, and clicking on or near an unfixed top or bottom edge will fix the height if there is a vertical strut connected to the container.

[0210] Manipulating edge, axis, width and height fixedness correspond to a transition between edge states for the container. Other manipulations, such as changing the position of a fixed edge or corner, modify other container state information.

[0211] Preferably, in order to ensure each container always has a valid edge state, a set of rules is applied each time a constraint is added or removed from a container, and necessary adjustments are made to other constraints so as to resolve any problems. Adjustments are immediately indicated to the user by updating the screen display to show the new constraint configuration. This causes the user interface **103** to prevent containers attaining an undesired state.

[0212] Rules are applied individually to the horizontal and vertical dimensions of each container as follows:

[0213] 1. If any edge becomes fixed or acted upon by an external constraint, the axis parallel to that edge becomes unfixed.

[0214] 2. If an axis becomes unfixed, at least one parallel edge must become fixed or acted upon by an external constraint.

[0215] 3. If opposite edges become unfixed and all external constraints on those edges are removed, the axis parallel to those edges becomes fixed.

[0216] 4. If an axis becomes fixed, edges parallel to the axis become unfixed and external constraints acting upon those edges are removed.

[0217] 5. If the width becomes fixed, the left and right edges and vertical axis become unfixed.

[0218] 6. If the height becomes fixed, the top and bottom edges and horizontal axis become unfixed.

[0219] 6.3.4 Alternative Container User Interface: Separate Constraints

[0220] An alternate (second) implementation of the container user interface may display and allow editing of containers in a way that divides the edge state of a container into visually distinct and separately editable constraints.

[0221] In this implementation, width and height constraints are indicated by bars across the content area of a container. Edges only indicate the fixed or unfixed nature of an edge.

[0222] The rules for the second implementation according to container display method are, in order:

[0223] 1. for each edge or axis, if that line is fixed, draw it solid, otherwise draw it dashed;

[0224] 2. if the width is fixed, draw a width bar across the content area, otherwise draw it dashed;

[0225] 3. if the height is fixed, draw a solid height bar down the content area, otherwise draw it dashed; and

[0226] 4. for each pair of perpendicular edges and/or axes, at their intersection draw an anchor if both are fixed, otherwise draw a handle.

[0227] There is no need for sliders, as previously described, in the second implementation, since a solid line already indicates the same behaviour a slider would. This is not true for the previous implementation, since that implementation uses solid lines to indicate width and height constraints in addition to the fixedness of an edge.

[0228] The width and height bars of the second implementation are a graphical means of displaying and editing width and height constraints on the container, respectively. The bars may look like edges, having solid or dashed appearances to indicated fixedness and un-fixedness respectively. In **FIG. 38**, a width bar **3805** and a height bar **3806** are shown spanning two containers **3802** and **3803**, whose horizontal and vertical positions respectively are determined by the size of container **3801** and the length of the connecting struts **3804**. Optionally, the bars might be inactive or not drawn if other constraints, such as fixed edges, would make fixing the width or height meaningless. For example if the left edge of a container is fixed and the right edge is unfixed, it may be desirable to prevent the user from fixing the width, since this would take the container to an edge state which is outside the set of 36 preferred edge states discussed earlier. In that situation, the width bar might not be shown.

[0229] To edit containers in this second implementation, clicking on an edge, axis, or width or height bar, using the mouse **133** and pointer **313**, changes the edge from fixed to

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unfixed, or vice versa. Dragging an edge, handle or anchor works in a similar manner as described, and the clicking on an anchor fixes any unfixed edges or axes which intersect it, or if both intersecting lines are already fixed, both become unfixed. If this leaves the container with either its horizontal or vertical positions poorly defined, fixing either or both of the central axes may correct this problem. For example, if clicking on an anchor leaves the container with all edges unfixed, there may be multiple possible content locations, and hence to correct this problem the container's mid-point could be anchored by fixing both its vertical and horizontal axes. Other external constraints or rules might make this step unnecessary or fixing only one axis might be sufficient.

[**0230**] 6.3.5 Alternative Container User Interface: Size Frames

[**0231**] In another (third) implementation, the behaviour of the container is controlled by direct manipulation of the minimum and the maximum extents, each of which is represented by a separate rectangular frame.

[**0232**] **FIGS. 6A-6C** illustrate third exemplary rules for a container.

[**0233**] Referring to **FIG. 6A**, a container **601** comprises a minimum extents frame **602** with control points **603** placed at each vertex and optionally at the center of each edge, and a maximum extents frame **604** with control points **605** placed at each vertex and optionally at the center of each edge.

[**0234**] The minimum extents frame **602** always appears inside, or coinciding with, the maximum extents frame **604** in both the horizontal and vertical dimensions.

[**0235**] A third frame **606** represents the actual extents of the content inside the container. The content frame **606** always appears inside, or coinciding with, the maximum extents frame, and always appears outside, or coinciding with, the minimum extents frame. The preferred size of the content frame is determined by factors such as the size and shape of the content inside the container and any other constraints that may apply to the container.

[**0236**] In order for the user to easily distinguish the three frames from one another, each frame and its control points may optionally be represented by different line weights, styles or colors.

[**0237**] In order to reduce visual clutter when viewing a document template comprising one or more containers, the minimum and maximum extents frames and their associated control points **602**, **603**, **604**, **605** and the content frame **606** may optionally be hidden unless the particular container to which they relate is made 'active', for example by placing the pointer within the area occupied by the container or by clicking over the container with a mouse.

[**0238**] Both the minimum extents frame **602** and the maximum extents frame **604** can be resized by direct manipulation of their respective control points **603**, **605** using the pointing device **133**. By resizing the minimum extents frame **602** the user can determine the minimum possible size of the content frame **606** regardless of what content may appear inside the container. By resizing the maximum extents frame **604** the user can determine the maximum possible size of the content frame **606** regardless of what content may appear inside the container.

[**0239**] When resizing the minimum extents frame **602**, should the position of any vertex or edge of the frame be dragged outside of the maximum extents frame **604**, either the vertex or edge will be automatically moved so that it is equal with the corresponding vertex or edge of the maximum extents frame after the control point is released, or the vertex or edge will cease to move any further after it has reached the corresponding vertex or edge of the maximum extents frame **604**, or the corresponding vertex or edge of the maximum extents frame **604** will be automatically expanded so as to be coinciding with or outside the vertex or edge being dragged.

[**0240**] When resizing the maximum extents frame **604**, should the position of any vertex or edge of the frame be dragged inside of the minimum extents frame **602**, either the vertex or edge will be automatically moved so that it is equal with the corresponding vertex or edge of the minimum extents frame after the control point is released, or the vertex or edge will cease to move any further after it has reached the corresponding vertex or edge of the minimum extents frame **602**, or the corresponding vertex or edge of the minimum extents frame **602** will be automatically contracted to as to be coinciding with or inside the vertex or edge being dragged.

[**0241**] The position of the content frame **606** within the maximum extents frame **604** is determined according to the relative position of the minimum extents frame **602** within the maximum extents frame **604**.

[**0242**] The minimum extents frame **602** can be moved to any position within the maximum extents frame **604** by dragging it with the pointing device **133**.

[**0243**] Optionally, the minimum extents frame **602** may be programmed to 'snap' to the closest of a selection of preferred positions within the maximum extents frame **604** including left, right and centered in the horizontal dimension and top, bottom and centered in the vertical dimension whilst it is being dragged with the pointing device **133**.

[**0244**] The horizontal dimensions a, b, c and d in **FIG. 6A** indicate the distances between the respective vertical edges of the maximum extents frame **604**, the content frame **606** and the minimum extents frame **602**.

[**0245**] Given any size of the content frame **606** as determined by the content inside the frame at any particular time, the dimensions a, b, c and d will always conform to the following equation:

$$a:b=d:c$$

[**0246**] A corresponding equation applies to the corresponding vertical dimensions, which are not labeled in the figures.

[**0247**] Thus, the position of the content frame **606** within the maximum extents frame **604** is determined according to the resolved horizontal dimensions a, b, c and d and the corresponding vertical dimensions.

[**0248**] **FIG. 6B** illustrates one particular case whereby the minimum extents frame **602** is located at the top and to the left of the maximum extents frame **604** and therefore the content frame **606** is also located at the top and to the left of the maximum extents.

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[0249] **FIG. 6C** illustrates another particular case whereby the minimum extents frame **602** is located centrally within the maximum extents frame **604** in both the horizontal and the vertical dimensions, and therefore the content frame **606** is also located centrally within maximum extents in both the horizontal and the vertical dimensions.

[0250] **FIGS. 6D and 6E** show a method **620** of generating variable data documents in which container extents are used. The method **620** is implemented within the application **121** and has a start point **622** after which in step **624** a document template is retrieved and displayed within the GUI **301** on the display **144**. Step **626** detects the drawing of a container by the user, typically via movement of the mouse **133** and the corresponding pointer **313**.

[0251] The container when drawn has, by default, two constraints being minimum container extents and maximum container extents such as those shown in **FIGS. 6A-6C**. In the initial state of the container, the minimum container extents coincide with the maximum container extents. In step **634**, the control points of either extent may be manipulated to thereby modify the container extent.

[0252] The container is represented in the template to form a layout after which various constraints may be applied in step **628**. Step **628** may include to incorporation of numerous types of constraints as described herein amongst containers in the layout. In the presently discussed implementation, the constraint being applied is that of a container extent such as those shown in **FIGS. 6A-6C**. In step **630**, a container extent is drawn, again using the mouse **133** and pointer **313** and, in step **632**, associated with a container in the layout. In step **634**, the control points of the extent may be selected and manipulate to thereby modify the container extent. Such modification may include setting one or more edges of the extent to coincide with edges of the container **(FIG. 6B)**, and moving or positioning the extents frame relative to the associated container.

[0253] Step **636** follows where the user may apply further constraints, by returning to step **628**. The further constraint may include a further extents frame, thereby affording the opportunity to construct both minimum and maximum extents frames. Other constraints may also be applied. For example, a strut may be applied between a maximum extents frame a further container not associated with the maximum extents frame. Such may allow the extents frame to dynamically move according to changes of the further container, whilst continuing to constrain the size of the container associated with the maximum extents frame.

[0254] After step **636**, through operation of step **638**, the user may add further containers to the layout until such time as the layout is complete. Once the layout is complete, step **640** places a record of content into the layout to generate a document. Step **642** enables this process to be repeated for all records of content thereby creating a set of variable data documents. Once all records have been consumed and documents generated, such may be proofed (see Sections 11.10-11.13) and/or printed as required in step **644**. The method **620** ends at step **646**.

[0255] 7. Image Containers

[0256] An image container is a particular type of container the purpose of which is to contain an image such as a photo, illustration, logo or diagram.

[0257] Desirably, image containers can have one of a selection of behaviors to control scaling of the image to be contained thereby, those including:

[0258] 'Fit entire image', whereby the image is scaled up or down so that the entire image fits within the container and the aspect ratio of the image is maintained

[0259] 'Fit image to size of box', whereby the image is scaled up or down so that the entire container is filled by the image and the aspect ratio of the image is maintained, with any remaining portions of the image cropped from view

[0260] 'Stretch to fit', whereby the image is scaled up or down to exactly fit the size of the container in both the horizontal and vertical dimensions, ignoring original aspect ratio of the image

[0261] 'Do not scale', whereby no scaling is applied to the image and any portions of the image that fall outside of the container are cropped from view.

[0262] Additionally, image containers can be set so that any image that is inside the container and smaller than the container is aligned to a particular direction, being any combination of left, center or right in the horizontal dimension and top, center or bottom in the vertical dimension.

[0263] 8. Text Containers

[0264] A text container is a particular type of container the purpose of which is to contain a range of text which may be formatted with various font and paragraph styles and may be aligned or justified to various edges of the text container.

[0265] Text containers contain either static text, variable text, or a combination of both. Other objects such as images can also be inserted into text containers and will flow in the same way text flows.

[0266] Static text is entered by typing directly into the container. Variable text is added by dragging a variable data object from the library into the container as described in more detail in Section 11. More than one variable text object can be displayed in a single text container.

[0267] Formatting of static text can be applied to individual letters, words or entire paragraphs, however formatting options can only be applied to the entire instance of a variable text item.

[0268] 8.1 Text Formatting

[0269] Text formatting includes the following options:

[0270] Font

[0271] Font Size

[0272] Bold

[0273] Italic

[0274] Underline

[0275] Color

[0276] Line Spacing

[0277] Force Capitalization

[0278] Automatic Hyphenation

[0279] 8.2 Alignment

[0280] The following text alignment options are allowed in some specific implementations:

[0281] Horizontal Alignment: Left (default), Horizontally Centered, Right or Justify.

[0282] Vertical Alignment: Top (default), Vertically Centered, Bottom.

[0283] Other options may be appropriate in different implementations, such as vertically justified text.

[0284] 8.3 Columns

[0285] Text in a text container may be arranged either in a single column, or in two or more vertical columns, with a space known as a 'gutter' separating the left and right edges of each column from each adjacent column.

[0286] While it is common in the prior art for column widths to be adjustable by dragging a dividing line between adjacent columns, gutters have previously been set by altering a value in a property sheet or dialog box or by a similar non-direct method.

[0287] **FIGS. 7A-7B** illustrate a text container **701** with three columns and a method by which both the column and gutter widths can be resized by direct manipulation using a pointing device such as the mouse **133** and the pointer **313**.

[0288] Referring to **FIG. 7A**, the text container **701** is divided into three columns **702** of text. As illustrated, lines **703** represent the central dividing lines between adjacent columns, and lines **704** represent the gutter boundaries between adjacent columns **702**.

[0289] By dragging the central dividing line **703** with a mouse **133** and pointing device **133**, the width of the adjacent columns can be adjusted. A special pointer **705** is displayed during the drag function in place of the default pointer, to indicate that the column drag function is active.

[0290] As illustrated in **FIG. 7B**, by dragging a gutter boundary line **704** with a pointing device, the width of the gutter can be adjusted. A special pointer **706** is displayed during the drag function in place of the default pointer, to indicate that the gutter drag function is active.

[0291] Both gutter boundary lines within the same inter-column space are adjusted simultaneously so that equal spacing is always maintained between each of the gutter boundary lines and the central dividing line.

[0292] As also seen in **FIG. 7B**, where there are more than two columns, each gutter is able to be manipulated independently.

[0293] 8.4 Variable Font Size

[0294] The font size of the text inside a text container may be varied to allow various volumes of text to fit inside the container by shrinking or growing to fit, and to allow the size of the container to vary according to external constraints, whilst still allowing the text to fit wholly inside the container. A minimum and a maximum font size may be set for each text container, constraining the possible range of font sizes. A binary search algorithm may be used to determine the optimal font size to use in order to fit all text within the container. If the font size reaches the minimum size, and the text still does not fit within the container, an error can be shown to the user.

[0295] 8.5 Font Size Synchronization between Containers

[0296] A constraint may be created between two or more text containers specifying that the font size must be equal in all containers regardless of whether the font size of any of the containers is altered to allow certain text content to fit properly within it.

[0297] Preferably, if the text containers selected for this synchronization have different font sizes prior to the addition of the constraint, the font sizes are first averaged and applied to each selected container. An alternate implementation may use the font size of the first selected container and apply that font size to all other containers. A further alternative is to apply an external font size setting to each container.

[0298] Referring to **FIG. 8**, the application window **301** has a toolbar area **303** as described previously. The toolbar area **303** contains at least a font selector **803**, a font size selector **804** and a button **805** for adding the font size synchronization constraint. The font selector **803** and the font size selector **804** may be used to change the properties of the text in a text container. Clicking on the font size synchronization button **805** when several text containers are selected will synchronize the font sizes of all selected containers.

[0299] A plurality of text containers **806**, **807** have been previously placed in the document template **309**. The containers may be selected by operating the mouse **133** by clicking on the containers with the pointer **313**, by dragging a selection rectangle around them or by another method. A visual means may be used to indicate that the text containers are currently selected, such as by showing control points on the containers.

[0300] The constraint is added by selecting two or more text containers **806**, **807** and by activating the synchronize button **805**. In other implementations, the font size synchronization constraint may be applied by pull a down menu, keyboard command or other means.

[0301] The constraint may optionally be indicated in the user interface by way of an icon **808** or other graphical representation on or near the respective text containers **806**, **807**. Additionally a joining line **809** may optionally be drawn between the respective icons of the text containers linked by constraints to indicate which text containers are linked to each other.

[0302] In other implementations, a separate area of the video display screen **144** may be provided for displaying various properties of selected objects, and this area may be used to indicate that a selected text container has a font size synchronization constraint applied to it, and to identify which other containers are linked by the constraint.

[0303] A font size constraint may be deleted by selecting one or more of the text containers linked by the constraint and repeating the command or sequence used to apply the constraint initially. This may be achieved by activating a synchronize button **805**, by selecting one or more of the text containers linked by the constraint and applying an additional command or sequence specifically provided for the

purpose, or by clicking on a representative icon **808** or joining line **809** and applying a command or sequence such as actuation of a 'delete' key on the keyboard **132** or from within a menu command shown on the display **144**.

[**0304**] If the user applies the font size constraint to two or more text containers that already contain text with different font sizes, either the largest, the smallest or the average font size will be applied to all of the text containers. Alternatively the user can be prompted to choose the font size with a pop up dialog box or similar.

[**0305**] If the user manually changes the font size for any of the containers already linked by a font size constraint, for example by selecting a new font size from the font size selector **804**, the new font size is applied to all of the containers linked by the constraint.

[**0306**] 8.6 Automatic Application of Internal Margins

[**0307**] The internal margin of a text container may automatically be set based on whether the text container has a visible border and/or a visible background.

[**0308**] Referring to **FIG. 9**, the application window **301** has a toolbar area **303** as described previously. The toolbar area **303** contains at least a border selector **903** and a background color selector **904**.

[**0309**] A text container **905** has no visible border or background color, and there is also no margin between the edges of the container and the text inside the container.

[**0310**] A text container **906** has a visible border, and has a margin **907** between the edges of the container and the text inside the container on all four sides.

[**0311**] In events preceding the state of the system as illustrated in **FIG. 9**, text container **906**, in a state similar to text container **905** with no visible border or background and no internal margin, is selected by clicking on the container **906** with the pointer **133**, by dragging a selection rectangle around it or by another method. A visual means may be used to indicate that the text container is currently selected, such as by showing control points on the container.

[**0312**] A visible border is then applied using a border selector **903**, or alternatively a background color is applied using a background color selector **904**.

[**0313**] At the time the visible border or background is applied to the text container, if there is no internal margin set, a pre-determined internal margin **907** is automatically applied to the text container on all four sides. An internal margin may be automatically added whenever there is a visual distinction between the background color of a text container and the predominant surrounding background color of the template.

[**0314**] Another situation in which an internal margin might be automatically set for a container is if the container's background color differs from the page color. In this case, an internal margin might be added to provide a visual separation between content and the page background, rather than allow content to flow up to the edge of the container. If the container's background color is fully transparent, then by definition its contents will be drawn on the same background as the page and so no internal margin need be added.

[**0315**] 8.7 Text Flow between Containers

[**0316**] Two or more text containers may be linked together in a sequence in order to allow text to flow from one container to the next, should the volume of text exceed the size of the preceding container.

[**0317**] When the text does not fit in the combined area of all such linked containers, it is necessary to find a font size for each container that allows the text to fit, while trying to maintain the relationship between the font sizes of the different containers.

[**0318**] One desirable method to achieve this for a set of linked containers is to use a binary search algorithm to scale the font sizes for each container until the text just fits, or all linked containers would reach a font size smaller than their respective minimum font size (at which point there is an error or other indication to the user that the operation could not complete). Note that if one container reaches its minimum font size before the other, this does not necessarily cause the algorithm to terminate. In such circumstances the algorithm attempts to maintain the font size relationships between containers, but does not guarantee to do so.

[**0319**] An alternate method to achieve this is to use a similar method to the above, but terminate with an error or other notification if any of the linked containers reach a font size smaller than its minimum font size. This alternate method preserves the relative font sizes between linked containers, but may produce errors and fail to produce a solution in more cases than with the binary search algorithm. The alternate method would be used to implement text flow where font size synchronization between all the linked containers is also desired.

[**0320**] Another method to achieve text flow with font shrinking is to simply reduce the font size of the first container in the linked set until either the text fits within the set of containers, or that first container reaches its minimum font size. If the latter, continue by shrinking the second container, and so on, until either the text fits or all containers are at their minimum font size. If the text still does not completely fit, indicate this somehow, possibly with an error notification. In this method, the ordering of the containers is significant and is defined as the order in which the text flows, so if the text begins in container A and continues in container B, then A is the first container and B is the second container.

[**0321**] 9. Guides

[**0322**] A guide is a vertical or horizontal line spanning the width or height of a page to aid the positioning of containers and other guides. There are two kinds of guide, fixed and unfixed (or floating). Guides may be connected to other guides or containers via struts (distance constraints, described later). Guides do not appear in documents, only in the document template **309** as an aid to design. Guides may be created by dragging a pointing device from a ruler area into a work area.

[**0323**] 9.1 Fixed Guides

[**0324**] A fixed guide is fixed to the page, or to some part of the page, such as the printable area. A fixed guide is fixed in the sense that it has the same position for all documents. Such a guide may be fixed relative to a particular edge of the page or printable part of the page, for example relative to the left edge. In this example, if the page was resized (for example to print on a different paper size) the guide would

remain the same distance from that left edge, but not necessarily the same distance from any other edge.

[0325] 9.2 Unfixed Guides

[0326] An unfixed or floating guide may have a different position in different documents, or when the data within a document changes, for example when a document template is merged with a record from a data source. In this example, when data is merged with a document template, one or more containers may hold data from the data source which could cause the position of an unfixed guide to be determined through the action of struts. Until such data is merged with the document template, the position of an unfixed guide might be unknown, or it might be given an initial (possibly arbitrary) position for the purposes of editing and design. In certain implementations, a floating guide always has a position that can be edited by the user or changed by the layout engine **105** when data from a data source is merged with the document template.

[0327] 9.3 Guide Implementations

[0328] In specific implementations, both fixed and unfixed guides are represented by a solid line which may extend up to the rulers at the edge of a work space, page boundary or page printable area. Color is used to distinguish fixed and unfixed guides. Alternatively, a fixed guide may be represented by a solid line while an unfixed guide could be represented by a dashed or dotted line.

[0329] Referring to **FIG. 12**, an unfixed guide **1204** has been previously created in the GUI **301** by dragging with the pointer **133** from the horizontal section of the ruler **308**. A first container **1201** has an unfixed edge **1202**. A strut **1203** has been created from the edge **1202** to the unfixed guide **1204**. A second container **1205** is attached directly to the guide **1204**, by virtue of the top edge of the container **1205** being aligned directly on the guide **1204**. A third container **1206** is connected to the guide **1204** by a strut **1207**. A fourth container **1208** is also connected to the guide **1204** by a strut **1209**.

[0330] As the unfixed edge **1202** moves as a result of a change in the height of container **1201**, the guide **1204** will change its vertical position to maintain the strut constraint **1203**. Containers **1205**, **1206** and **1208** will consequently move in order to maintain their constraints in relation to the guide **1204**. Similarly, if as the result of merging data with the document template, container sizes are determined or changed, the action of struts may cause unfixed guides to attain positions based on contents within those containers.

[0331] The method for adding a strut constraint between a container and a guide is similar to the method for adding a strut between containers, described in other sections of the description.

[0332] One preferred method for adding a constraint whereby an edge of a container is attached directly to a guide, for example container **1205** in **FIG. 12**, is either by the container or container edge being dragged to a position within a pre-defined distance of a guide, at which point it will visually 'snap' onto the guide; or similarly by a guide being dragged within a pre-defined distance of a container edge, at which point it will snap to the container edge. If the container, edge or guide is released from the drag operation while in the snapped state, the constraint will be created.

[0333] 10. Struts

[0334] Struts are a type of constraint used to maintain a fixed distance between particular edges of containers, and other objects such as guides and margins.

[0335] Preferably, each strut applies to exactly two parallel edges belonging to two different containers within the same document template, or to one edge of a container and a parallel guide, or between two parallel guides. Other implementations may restrict what struts may connect, or allow struts to connect edges of a single container as a way of specifying its width or height constraints, or allow struts to connect edges or guides with parallel page margins or edges.

[0336] Struts are symmetric, in the sense that neither of the edges attached by a strut has priority over the other edge in terms of placement.

[0337] The length of a strut may be represented either visually or numerically or by a combination of both. In certain implementations, all struts display their current length visually by the length of the graphical representation (the strut icon), while other properties are visible as numbers or visual settings within a dialog box.

[0338] Returning to **FIG. 4**, edge **410** of a first container **407** is connected to edge **411** of a second container **408** by a strut constraint. The strut constraint is indicated by strut icon **412** which may optionally be hidden in various modes of the application, for example in a preview mode.

[0339] Strut icons are usually hidden in the normal mode of operation, and are revealed when the pointer **313** associated with the mouse **133** is in the vicinity of the strut or the containers or edges or guides connected to the strut. The vicinity can include any other strut, container, edge or guide which is connected to the strut either directly or indirectly via any number of struts.

[0340] Since a strut only has length in one dimension, the strut position in that dimension can be derived from the current positions of the edges to which the strut is connected. Hence, the strut **412** is drawn between edges **410** and **411**. A strut's position in the perpendicular dimension can be calculated in various ways. One approach averages the mid-points of the connected edges and locates the mid-point of the strut at the average. Hence, the mid-point of strut **412** is exactly half-way between the mid-points of edges **410** and **411**.

[0341] The contents of a container may vary between documents and hence any unfixed edges of the container may be in various positions relative to the page for different documents. The action of a strut constraint is to maintain distances between edges or guides, thus edges or guides connected by struts may have a restricted range of possible positions within documents.

[0342] Referring to **FIG. 4**, should a first edge **410** of the container **407** move, for example if the user manipulates an edge via the user interface using the pointing device **313**, the second connected edge **411** may be 'pushed' or 'pulled' in order to maintain the strut constraint **(412)** between the two edges. Although the user may perceive the operation of struts as pushing or pulling connected edges or guides, the actual operation in the user interface is the same as that used in producing documents.

[0343] In another implementation, while the strut tool is activated, the method described above by which struts are revealed may be modified, such that all struts are revealed whenever the strut tool is activated. Alternatively, the struts are only revealed when the pointer is directly over the strut, with no other struts being revealed at that time.

[0344] Although, as illustrated in **FIG. 4**, the edges **410** and **411** connected by strut **412** are adjacent and opposite to each other, struts can be applied to any two parallel edges of separate containers regardless of whether the edges are adjacent to or opposite each other or neither.

[0345] **FIG. 11** illustrates a strut between containers, illustrated using the third set of exemplary rules for a container described earlier with reference to **FIGS. 6A-6C**. A first container **1101** has a minimum extents frame **1103**, a maximum extents frame **1105** and a content frame **1104**. A strut **1106** is connected to the respective edge of the content frame **1104**. A second container **1102** is shown whereby the minimum and maximum extents are equal. Therefore the container **1102** has a fixed size in this configuration. The strut **1106** acts on the entire container **1102** which, as a result, may be pushed or pulled in a horizontal direction.

[0346] Accordingly, struts may be created between any edge of the content frame of a first container and a parallel edge of either the maximum extents frame or the content frame of a second container, or a parallel guide, margin or other object.

[0347] 10.2 Creating Struts between Containers

[0348] Referring to **FIG. 10**, a new strut can be created first by activating a strut tool by clicking on a strut tool button **406** in the toolbar area **303** using the mouse **133** and pointer **313**. Then, one of two operations may be performed to link two containers. Firstly a path **1004** can be dragged by depressing and holding the mouse **133** at any point **1003** inside the first container **1001** and dragging the pointer **313** to end at any point inside the second container **1002**, at which point the press of the mouse **133** is released. This is illustrated by the position of the pointer **313** in the **FIG. 10**. Alternatively, a strut between the containers **1001** and **1002** may be formed by clicking (ie. depress and release) the mouse **133** first at any point **1003** inside the first container **1001** and then a second clicking at any point inside the second container **1002**, as illustrated by the position of the pointer **313** in **FIG. 10**.

[0349] In a specific implementation, the strut creation process described, as well as selecting the two containers to be connected, also selects the connected edges of the containers on the basis of the closest proximity of the starting and ending points of the path **1004** to the various edges of the respective containers. For example, the starting point **1003** is closer to right hand edge **1006** than it is to left hand edge **1005** of first container **1001**, therefore right hand edge **1006** will be connected. Similarly, the left hand edge **1007** of second container **1002** will be connected.

[0350] In an alternate implementation, edges selected may be the closest pair of parallel adjacent edges from both containers, for example edges **1006** and **1007** respectively of containers **1001** and **1002** as shown in **FIG. 10**.

[0351] In yet another implementation, edges selected may be the edge that is first crossed by the path of the pointer as it moves from the inside to the outside of the first container, and the edge that is first crossed by the path of the pointer as it moves from the outside to the inside of the second container.

[0352] In order to aid the user in selecting an appropriate second edge, after the first point **1003** of the strut has been defined, potential second edges may be graphically indicated as the pointer moves into proximity, such as by varying the line style of the edge or by displaying an icon in the vicinity of the edge. Only edges that will potentially create a valid strut will be indicated, including parallel edges on containers other than the container defined by the first point.

[0353] Additionally, if struts are non-symmetric, for example if a strut were to treat each of its connected edges differently for some reason, the strut creation process described can indicate this graphically. For example, since starting point **1003** is inside first container **1001**, and the ending point is inside second container **1002**, edge **1006** of the first container may be treated differently from edge **1007** by the operation of the strut, and the strut may graphically indicate that fact.

[0354] 10.3 Creating Struts between Guides

[0355] The creation of struts between guides is similar to that of creating struts between edges of containers described above. Since guides do not have width and height in the way that containers do, there are fewer possible user interfaces. Another approach allows a strut tool **406** to be selected and then the first guide is selected and the pointing device is dragged to attach the strut so created to a second guide.

[0356] Another implementation allows two guides to be selected and then a strut creation button (icon) is selected which creates a non-directional strut between the guides. A directional strut may be created by another implementation by considering the order in which the guides were selected as a way to distinguish which is the driving edge and which is the driven edge.

[0357] 10.4 Creating Struts between Guides and Containers

[0358] In one implementation, dragging a guide onto an edge of a container creates a distance constraint, typically specifying a zero-distance between the guide and the edge. This distance constraint may be represented by a strut, hence, such a method of dragging a guide (either during construction of the guide or container or while editing) might actually create a strut.

[0359] Desirably struts can be created between guides and container edges in a similar fashion to how struts may be created between container edges (select tool, click edge or guide, drag, release).

[0360] 10.5 Creating Struts to Margins

[0361] It may also be desirable for distance constraints to exist between a page margin and guides or container edges. Struts can be used for this purpose. In some implementations this is not necessary, since guides and container edges may be fixed in position relative to an edge of the page, which has the same effect as a strut. A strut between a page margin and a guide or container edge is also unnecessary since a guide may be created which is fixed relative to the desired page margin, and other guides and container edges may then be

linked via struts to it. Hence, there is no need for struts to be able to link page margins to guides or container edges.

[0362] In another implementation, guides and container edges might not have the ability to be fixed relative to a page margin. In this situation, it may be desirable to use struts to represent distance constraints to page margins.

[0363] 10.6 Interactions between Struts and Containers

[0364] Struts interact with containers in many ways. The simplest operation of a strut is to restrict where edges of containers and guides may be positioned, as a way of determining where content will be placed in documents. However, the connection of a strut to a container may also modify the state of the container, in particular its edge state, in keep the container within the set of allowed states.

[0365] Rules governing the attachment of struts to containers in a specific implementation are:

[0366] 1. If a strut is connected between two fixed edges, the selected edges become unfixed.

[0367] 2. If a strut is connected between two fixed edges, the second selected edge becomes unfixed and if the length of the container in a dimension corresponding to the orientation of the strut is fixed, then both edges perpendicular to the strut are unfixed, while the length of the container in said dimension remains fixed. For example, if the second selected edge is a vertical edge of a fixed width container, then both vertical edges of the container will be unfixed so that the container becomes movable horizontally while its width remains fixed.

[0368] 3. If both container edges and/or guides attached to a strut become fixed, remove that strut.

[0369] 4. If a fixed container edge or guide is moved by the user, the length settings of any strut attached to it may be modified such that the other edge or guide connected to the strut remains unchanged.

[0370] 11. Variable Data

[0371] The user interface **103** allows the user to associate a data source with a variable document template and design the template to produce valid documents upon merging of the data source with the template. Merging is performed interactively, in the background, or on demand by the layout engine **105** component of the software application **121**.

[0372] Preferably the data source is associated with the variable document template interactively and the layout engine **105** merges and lays out pages of the document on demand as the user interactively navigates the merged document. Another implementation may merge data with a template and print the merged document without requiring an interactive user interface during the merging process. Another implementation may merge data with a template, producing a merged document, in the background and alert the user to problems in the merging process by messages which appear asynchronously with respect to the user's navigation of a merged document.

[0373] 11.1 Data Source Selection

[0374] To merge a variable document template with a data source it is necessary for an appropriate data source to be associated with the template. One method for achieving such an association is through the use of a data source selection window, as illustrated in **FIG. 13**, and which forms part of the user interface **103**.

[0375] **FIG. 13** shows a GUI window as presented on the display **144** by the U' application **103**, which allows the user to interactively select a data source, which might be a database, a file, a join of a plurality of databases, or some other source of information. Once a source has been selected, as illustrated in **FIG. 14**, the source is associated with the template until explicitly or implicitly disassociated.

[0376] 11.2 Data Filtering

[0377] It is possible that not all of the data within a data source may be valid for a particular merging operation. When such does occur, there are numerous possible ways for the user to restrict the range of data that is to be used. One implementation is to allow algorithmic data filtering, to restrict the kinds and amounts of data that are to be used. For example, a range of postal zip codes might be selected so that only certain records associated with a desired geographic region are used to generate documents. Such algorithmic filtering is well known in the art. Another implementation might be for the user to select and mark data, which are to be used, via a user interface, after the data source has been associated with the template.

[0378] **FIG. 17** shows the preferred approach of how the user can access a data filtering operation via the GUI **301** of user interface **103** which occurs after a data source has been associated with a variable document template, via selection of a menu item.

[0379] 11.3 Data Sorting

[0380] Related to filtering is the ability to sort a data set into a sequence in order to find relevant data. One implementation allows the user to select a sorting of the records of the data source based on a user-chosen 'key' variable of the data source. All records are ordered by ascending alphabetic order in the chosen key variable. For example, if the key was the variable "Name", then after the sort operation is performed, records for which the Name starts with the letter A would be encountered before records for which the Name starts with the letter B (in the case of English text). Part of a suitable user interface is shown in **FIG. 15**, which shows that sorting may occur as part of the process of selecting a data source. Sorting is also possible after a data source has been associated, via a menu selection as shown in **FIG. 17**.

[0381] Another implementation may allow user-selectable sorting methods, such as numeric or language-specific methods, for different kinds of data. Another implementation may automatically select a sorting method based on the kinds of information stored the selected key variable, perhaps with an override mechanism in case the automatically selected method is a poor choice.

[0382] 11.4 Record Navigation

[0383] A data source contains records, each of which is a collection of related information. For example, a database might contain records describing customers, or it might contain records of products. It is useful if the records within a database can be ordered into a sequence and navigated by the user.

[0384] A preferred navigation method is to display a set of GUI buttons which can be activated by the pointing device **313** and the mouse **133**, as shown in **FIG. 18** by the symbols **1805**. Each button steps forward or backward through the sequence of records either one by one, or step to the start or end of the sequence, or step by some number of records. One approach is also to include a menu activated by the pointing device **313**/mouse **133** or the keyboard **132**, which shows these options (as shown in **FIG. 17**), and additionally allows the user to navigate to a particular numbered record.

[0385] Upon navigating to a particular record, the software application **121** displays that current record in some way upon the display screen **144**. This may occur by merging that record with the variable document template and displaying the index of the current record within the sequence.

[0386] 11.5 Variables

[0387] Each data source can be composed of a plurality of named variables that apply to records within that data source. For example, a customer data source might have variables for customer name and customer address. These are variables since the values may differ for each record, although the names of the variables might be the same for every record.

[0388] It is useful to have a method of displaying variables so that the user can inspect the records within the data source and choose variables to be associated with the variable document template.

[0389] A preferred method for displaying variables is to list each variable by name and current value vertically within a free-floating window, as shown in **FIG. 18**. The current value is determined by examining the current record and finding each variable's value in the data source for that record. The current record may be chosen as outlined earlier using record navigation. Note that not all of the values or variable names need be displayed. There may be navigation mechanisms to allow the user to see each variable or value if there is too much information to fit within the window. Another implementation may use a similar display which is part of another window (in other words, a sub-window). If there is no data source associated with a document template, the window would be empty of variables, as shown in **FIG. 16**.

[0390] Variables may contain several kinds of data. A variable might store textual values, or it might store images. These are referred to as Text Variables and Image Variables respectively in the discussion below.

[0391] Preferably, the variables of a data source have one kind of value, hence a variable might display text or an image, but not both. A different implementation is to allow the variables of a data source to store different kinds of data per record. For example, in one record a product description variable might contain a textual description, while in another record in the same data source the same variable might have an image value.

[0392] 11.6 Text Variables

[0393] A Text Variable contains textual values within each record of the data source. The application **121** signals to a user that a variable is a Text Variable by placing a distinctive label next to the name of the variable within a list of the variables in a data source, as shown in **FIG. 18** by the label **1801**. Another implementation might display the value of a variable near the variable's name as a way to signal a variable's type, as shown by the text **1802**, although such an approach alone is not guaranteed to be unambiguous since image data might happen to appear the same as textual data in some circumstances. The application **121** uses this technique, but only as an aid to show the variable's data, not as a primary method of distinguishing variable types.

[0394] 11.7 Image Variables

[0395] An Image Variable contains image values within each record of the data source. The values may be image data in a compressed or uncompressed format, or a file name or other access method to locate an image resource. The application **121** signals to a user that a variable is an Image Variable by placing a distinctive label next to the variable's name within a list of the variables in a data source, as shown in **FIG. 18** by the label **1803**. Another approach is to display the value of a variable near the variable's name, as shown by the text **1804**, although this method is not guaranteed to be unambiguous since an image file name (for example) may be confused with textual data.

[0396] 11.8 Drag and Drop to Containers

[0397] It is useful to have a method for allowing the user to construct a variable document template while variables of a data source are visible, so that the user may know what variables exist. It is also useful to allow the creation of the appropriate type of container from a given variable.

[0398] The application **121** via the user interface **103** allows creation of the appropriate type of container by allowing the user to directly manipulate variables in the variable list (shown in **FIG. 19**) using the mouse **133** and the pointing device **313**. The user selects a variable (for example one of the rectangular areas marked **1902**) and drags it onto a design surface using the pointing device **313** and releases the selection **1906**. This is used as a signal that an appropriate type of container is to be created and initialized with that variable. For example, a Text Variable (as indicated by the label **1901**) which is dragged onto a design surface in this way will produce a Text Container which displays that variable's value for the current record (as also shown by text **1903**). If an Image Variable **1904** was dragged to the design surface, an Image Container results which then displays either the filename **1905** and/or the image itself, scaled, cropped and aligned, depending on the settings employed by the user.

[0399] The initial state of the Text Container so produced may be user configurable, but another approach is to anchor the container to the page using the location where the user released the selection as a hint.

[0400] It might not be possible to use the location as the exact location of the container since the location might be invalid, such as outside the design window or outside the page (if that is invalid), so the location might be a hint. The container may be centered on the location, or one of its corners might be positioned close to the location, or the container might be placed as close to the location as possible while not violating other constraints such as being completely within the page, or the container might simply be placed in a default or random position and the location

ignored. There are many possible implementations of a method to position a newly created object as the result of dragging a pointing device.

[0401] The application **121** also creates the container to be of sufficient size to store all of the current record's content for the variable so dragged onto the design. Hence a long piece of text will produce a large Text Container. Another approach may might pre-calculate a median size for the data in the dragged variable and produce a container large enough to display that median size. Other approaches can use variants of this method to create containers that are large enough to store the largest record's data, or the smallest, or some other algorithm.

[0402] Another approach is to drag the variable onto the design space and then sweep out a rectangle for the container that holds that variable's values. A further approach is to select the variable and then sweep out a rectangle for the container, without first performing a drag operation. Another alternative is to click twice with the pointing device on the variable representation and have a corresponding container appear at a random or algorithmically chosen location in the design.

[0403] Another implementation is to have all variables within a data source appear in the design as containers as soon as a data source is associated with the design, and for the user to then position or delete those containers as needed. The initial positions and sizes of containers created in this way may depend on the ordering of data within the data source and the relative sizes of content within each variable. In such an implementation, associating a data source with an existing design might not create a container for a variable if a container representing the particular variable already exists. This method is not preferred, since it does not facilitate the creation of multiple containers that refer to the same variable.

[0404] A specific implementation also supports linkage of data source variables with containers that have already been created. This allows a user to create a design without having to first associate a data source. Such an implementation may also provide association of a data source, creation of containers, and linkage of variables with containers in any order to support a flexible workflow.

[0405] Such an approach also allows existing containers to have their content modified by a drag and drop mechanism, implemented using the mouse **133** and pointer **313** combination, such that dragging a variable into a container may reassign what that container displays, or it might add to what it holds. For example, a container might have been constructed which contains the static text "Dear" and then the variable named "First Name" could be dragged into the container, and then the variable named "Last Name" could be dragged into the container. This may result in a container that displays all of these data, or it may result in a container that displays only the last variable's value, depending on the mode of operation and the settings on the container.

[0406] 11.9 Displaying and Navigating Multiple Documents

[0407] Since documents are the product of merging a document template with data from a data source, there could be many documents produced as the result of a single merge operation. There are many ways such documents can be navigated and displayed.

[0408] One implementation contains several ways to display and navigate the documents, and relies on 'live proofing' (described below) in which each record of the data source is merged on demand with the document template to produce a view of both the constraints of the document template and the data for a given merged document. For such an implementation, several possible user interfaces exist, depending on user settings and/or the nature of the documents produced. A summary of those user interfaces are as follows:

[0409] Each document is displayed in one flowing document that is organized vertically and/or horizontally, similar to a word processing document, or a spreadsheet, and navigated by scrolling mechanisms, a pointing device and/or keyboard. A separate mechanism may be used to navigate through the records in the data source, such as the buttons **1805** in **FIG. 18**.

[0410] Each record when merged can result in a document which has many pages. Those pages may be organized vertically and/or horizontally and displayed. A separate mechanism can be used to navigate through the records in the data source.

[0411] If a document template produces few pages when merged with each record, several documents may be displayed vertically and/or horizontally. For example, if each document is only one page in length, it is possible to arrange all documents into a linear sequence and display them using a windowing system and employ a scrolling mechanism to navigate the documents. This maps navigation both within a document and between records of the data source onto spatial navigation.

[0412] If each document has one or more pages, these may be organized horizontally and then the vertical direction may be used to step through the records of the data source by laying out each subsequent document below the document representing the previous record, thus navigating the space of documents using one dimension. The roles of horizontal and vertical directions may also be interchanged, with a similar effect.

[0413] In each of the above, there may be other ways to navigate between records and between page and/or documents, such as buttons, menus, and so on.

[0414] In an alternative implementation, the document template can be displayed separately from the merged documents. Merged documents are produced only in a 'print preview' form which cannot be edited but simply display the results of merging a single record with the template. In another alternative, the document template may be visible, as well as a non-interactive print preview, as well as a live proofing preview which allows editing of both the document template and preview of the merged documents. Other combinations of these work modes are possible.

[0415] 11.10 Proofing

[0416] In on-screen and printing jobs where variable data is used, significant productivity gains can be made by efficiently finding records that are representative of the full range of records being merged, and in particular, the actual

extreme cases from a set of variable data records, so that the user understands how the final merged documents will appear.

[0417] It is useful to preview and proof print a number of records to see how the merged document will be affected by different sizes of variable images and different lengths of variable text. The most useful sample records to print include:

[0418] how most of the records will print; and

[0419] records where there is either little or a lot of content being displayed. More complex extensions of the principle include:

[0420] when text has been reduced too small or reached its minimum size;

[0421] when any variable data text is not being displayed;

[0422] when an image is scaled up too much (print quality may be poor); and

[0423] when the aspect ratio of an image has been distorted too much.

[0424] When dealing with variable data, the number of records or versions of a document can be very large and without an automated proofing mechanism, the user would have to manually review each record to check that the final appearance of all of the merged documents are acceptable. For example, it is possible that only one of the records in the database contains content that will produce unpleasing appearances and finding that record can be difficult. This is particularly true for variable data jobs where the number of records is very large.

[0425] An efficient method of previewing and proof-printing variable data printing jobs is disclosed that ensures that the final appearance of every document is acceptable and will print correctly. A limited number of records are selected for previewing on-screen and/or proof printing which are representative of all of the other records that will eventually be printed. These records are selected by analyzing the merged appearance of every record and using a predetermined set of rules to determine those records that have the most significant impact on the appearance of the document.

[0426] Selective preview and proofing provides a profile of output results including extreme cases, so that the user is not surprised when printing the entire job. Showing extreme cases, being those records with the shortest and longest display sizes, is valuable and economic approach can be generalized to include a short list of "representative" cases that includes the median display size, most extreme cases and a number of records in-between the median and most extreme cases.

[0427] 11.11 Live Proofing

[0428] Live proofing is the process of displaying variable data merged with the variable document template interactively and on-demand. **FIG. 20** illustrates a graphical user **2000** interface in which a record of the data source having items **2010-2020** has been merged with the template to show **2002** what part of that record would look like if printed. Extra borders **2004** and colors **2006** have been added to make visible the constraints defined within the variable document template, but these artifacts are not intended to be printed.

[0429] Live proofing is advantageous over a separate merging process because errors in the design of the template are likely to be found earlier through interactive navigation.

[0430] A specific implementation of the application **121** uses live proofing. Alternative implementations may use live proofing as an option, or not at all.

[0431] 11.12 Selective Proofing

[0432] Selective proofing is a way of viewing only selected records in a Variable Data Printing application **121** that are either typical of the average document, or are least like the average document.

[0433] It is useful if the user can specify many kinds of items to measure during selective proofing. The following measures may apply to individual containers, struts linking containers, pages, records in the data source or variables in the data source. Collectively these things will be referred to as 'design items' in the discussions below of selective proofing. The term 'merged size' refers to a size measure of a design item after a record from the data source is merged with the variable document template. Various size measures will be discussed later.

[0434] When selective preview or selective proofing is activated, a design item is selected by the user interactively or by a preference setting. Every record is separately merged with the variable document template. For each record, the merged size of the selected design item is recorded (stored). These merged sizes are compared to find those records for which the merged size of the selected design item is:

[0435] smallest;

[0436] median, average or some other measure of the middle of the set; and

[0437] largest.

[0438] In order to find the most relevant records, the application **121** examines the actual display size of each record rather than just the number of characters. For instance "w" takes up more space than "i" and would have a greater impact on the size of a container and the overall appearance of the document.

[0439] Once these records have been identified, they are presented to the user for previewing on-screen and/or printing.

[0440] Users can also preview or proof print additional records from the merged documents to increase their confidence that all of the records in a variable data printing job will display correctly. Preferably, a deviation from the middle of the set is used to order the design items in a sequence so that records having the most different merged size for the selected design item are presented to the user first or most prominently.

[0441] 11.12.1 Minimum and Maximum Content Size

[0442] A useful measure of the size of a design item is to consider its smallest or largest width, height or content area. In the case of individual containers, these measures are simple to compute. In the case of struts linking containers,

either width or height will be meaningful, but not both, so area is not a meaningful measure. In the case of individual pages the sum of widths of containers or the sum of heights of containers or the sum of areas of containers may be used. In the case of records, the sum of these measures for all pages needed to display that record may be used. In the case of variables, all containers displaying the value of that variable in whole or in part may be used. Other approaches to select and total these measures can also be used.

[0443] 11.12.2 Typical Size

[0444] Another useful measure of the size of content is to consider the typical size for a given design item. The typical size may be the average width or height, or the average area, or the average of the sums of the areas, or the average of the sum of squares of the widths and heights, or other possibilities. Another measure is to use the median instead of the average for each of the above. Other statistical approaches may be used.

[0445] Any or all of these measures may be used to locate typical instances of a particular design item. For example, records for which a particular container has an area closest to the average area could be located.

[0446] 11.12.3 White-Space Size

[0447] White-space is another useful measure of how typical a design item is within the set of merged documents. White-space may be defined in many ways. For example, white space may be defined as the difference in area between the area of a container as defined by the constraints of the container and the area of content within that container when merged with a particular record, for example, if a container had a minimum size and the content does not fill that size. Alternatively, white space may be defined as the difference between the size of a container and the size of content of that container in one dimension only, such as width or height.

[0448] Maximizing white-space is similar to, but not the same as, minimizing content size, and vice-versa. They are not the same, since container constraints such as minimum dimensions play a part in the calculation. For instance, finding a record which has a maximal content area is not necessarily the same as finding a record which has a minimal white-space area.

[0449] 11.12.4 Most Different Size

[0450] Of particular interest to variable data printing is locating documents which are unusual. For this a measure of unusualness is required. Such a measure may be defined in many ways. One example of such a measure is to calculate the largest deviation from the median size for a design item. The size is defined for some measure of width, height, area, sum of width and height, sum of squares of width and height, and so on. This median size can be calculated by examining each design item in question for each record in the data source, finding the size of that item and then finding the medians of all sizes so determined. The largest difference between each design item's size and the median size can then be calculated and thus the design item(s) with the largest deviation can be found.

[0451] **FIGS. 21A and 21B** shows a method **2100** for calculating the average document, and the most disparate document using the widths and heights of the containers for each document. The method **2100** may be performed as a sub-module of the application **121**.

[0452] The procedure starts at step **2101**. Firstly, the method **2100** iterates through all records in the data source, calculating the position and dimensions of each container in the document starting with a first record at **2102** and using a process loop formed by steps **2103**, **2104** and **2105**.

[0453] At step **2106**, the method **2100** calculates the average (mean) width and height of each container in the document template, by adding the width and height across all documents and then dividing by the number of documents.

[0454] Once the average values of the width and height are known for each container in the document template, the method **2100** iterates through all the records starting at a first record in step **2107** and via a loop formed by steps **2108**, **2113** and **2116**. For each container in the document, defined by a further loop bounded by steps **2108**, **2111** and **2115**, the method **2100** calculates the difference between the width of the container and the average width in step **2109**, and the difference between the height of the container and the average height in step **2110**. Step **2110** squares each of these values, and adds them together, to give a figure for the document. Squaring the results means that values are emphasized more strongly the further they are from the average value.

[0455] Once the figure above is calculated, it is now possible to work out, for any given container on any given document, how close that container is to the average size. If the container has the lowest value, it is closest to the average. On the other hand, if the container has the highest value, it is the furthest from the average.

[0456] If the user wants to know which is the most average document or the most deviant document, the values for each container on each document are added together in step **2112**. A list is thus formed which is then sorted in step **2114** which concludes the method **2100**.

[0457] The document with the lowest value is closest to the average document over each of its containers. The document with the highest value is least like the average document. The user may then be shown as many of these documents as is required, such as the 5 worst documents, or the 10 worst documents.

[0458] Other approaches can perform the above calculations on different properties than the width and height of the containers. Other properties that may be useful are the size of the content, the font size (for containers where the font grows and shrinks), the white space area on the document, the lengths of struts, or the positions of container edges.

[0459] 11.13 Pre-Flight Check

[0460] Size measures of the kind discussed above may be used to discover typical, atypical or problematic design items. A "pre-flight check" is a term used within the variable-data printing field to describe an automated pre-print process that seeks to discover problems or other features of a merged document, before committing the entire job to hard copy printing.

[0461] This check can be as simple as determining that all records will print acceptably and do nothing extra, reporting

that there were no problems, or drawing attention to the problematic records in some fashion.

[0462] Preferably, a pre-flight check is performed at the user's request and alerts the user as to whether the check found no problems or whether it found problems. If problems were found, the first problem encountered can then be displayed to the user together with an explanation via some visual and textual method of the nature of the problem.

[0463] Another implementation can find and list all problems for the user to then investigate. This check may be performed in the background while the user edits the variable document template, to provide a continually updating list of problems in a window or sub-window. If the list is empty an entry indicating that no problems have been found could be substituted. This background check may occur only at times when the software is otherwise idle, may occur continuously, or for some other set of times or situations.

[0464] 12. Layout Method Overview

[0465] One aspect of the present disclosure is a method of laying out items on a page. A layout comprises a collection of items to be laid out and a set of rules or constraints that define where the items are to be placed in the layout. Several layout methods are described. These include:

[0466] 1. A model for defining layouts. The layout model defines the types and properties of items that can appear in layouts and the allowed rules or constraints for defining how the items should be laid out. A data structure may be used to store layouts in the working memory of the computer **101**. Several layout models are described in detail below.

[0467] 2. A means of creating and editing layouts. This includes of a set of operations that can be used to create layouts. These operations may be implemented as software functions that can be called to build a data structure in accordance with the layout model. These will be described in detail below.

[0468] 3. A means of calculating positions and dimensions of items in layouts. Given a layout defined by a set of items and rules, this layout calculation method specifies how the items are to be laid out in accordance with the rules and may be formed by the software **105** executing on the computer **101**. The means of calculating layouts will be described in detail below.

[0469] Preferably, the means of creating and editing layouts in accordance with a particular layout model, and the method of calculating positions of items for that layout model, are implemented together as a software component, being the layout engine **105**, previously mentioned. Note that the layout engine **105** does not include the user interface **103**. Many different user interfaces may be used together with the layout engine **105**, described previously with reference to **FIG. 1A**.

[0470] 13. Layout Models Overview

[0471] The layout models include a basic layout model and several extensions to the basic model. The basic layout model defines the basic properties of layout items, and the rules that can be used to define layouts. Several additional rules are also defined that are used to extend the basic layout model. Some combinations of rules are advantageous because they lead to a simple layout method. Other combinations are advantageous because they are simple for users of the layout method to understand.

[0472] The basic layout model and the additional rules will be described below. Several implementations will be described incorporating particular combinations of the rules.

[0473] 14. Creating and Editing Layouts Overview

[0474] A layout is typically associated with part of a page in a document. Creating and editing operations are assumed to operate on a layout that is initially created as an empty layout and are functions that are called by the user interface software **103**. The operations may also be performed by server software without direct input by a user while producing a document by combining data with a document template.

[0475] Operations used to create or edit layouts preferably do not correspond directly to the operations performed by the user of the software. A single action by the user is typically translated into multiple layout creation operations by the user interface software **103** or preferably by another layer of software that provides a higher-level interface to the layout engine **105** than the operations directly supported by the layout engine **105**.

[0476] The means of creating and editing a layout comprises at least operations for:

[0477] 1. adding items;

[0478] 2. removing items;

[0479] 3. adding rules; and

[0480] 4. removing rules.

[0481] Other operations may be added for modifying the items or rules. The exact forms of the editing operations depend on the specific layout model used. Many different forms are possible. These operations are described in detail below.

[0482] When adding items and rules to a layout, it is easy to add combinations of rules that are inconsistent in the sense that there is no possible placement of the items that can satisfy all of the rules. Such a layout is said to be over-constrained. Conversely, it is also possible that a given combination of rules may admit many possible solutions. For instance, there may be many possible placements of the items that satisfy all of the rules. Such a layout is said to be under-constrained. It is desirable to ensure that every layout has exactly one solution. Hence, in addition to the operations used to create a layout, the application **121** also incorporates means for ensuring that there is exactly one solution. This is incorporated into the layout creation means and into the means for calculating layouts.

[0483] Since it is desirable to prevent users from creating layouts that have no solution or more than one solution, consistency and uniqueness checking may be performed in conjunction with editing operations. Such checking may be performed after each editing operation to test if the operation is valid. If not, the change may be disallowed and suitable feedback may be given immediately to the user.

[0484] Thus consistency and/or uniqueness checking may be incorporated as part of the editing operations. Alterna-

tively, the layout calculation can ensure that a single well-defined solution is calculated for each possible layout that can be created using the layout creation and editing operations.

[0485] A means of ensuring existence and uniqueness of layout solutions will be described in detail below.

[0486] 15. Layout Calculation Overview

[0487] For each layout model, there is a corresponding method of calculating the positions and dimensions of the layout items. These positions and dimensions may be defined in any two dimensional coordinate system that is convenient for the problem.

[0488] Several methods may be used for calculating the positions and dimensions of layout items. These include:

[0489] 1. the tree traversal method;

[0490] 2. the simplex method;

[0491] 3. a modified simplex method with a quadratic objective function; and

[0492] 4. graph based layout.

[0493] The tree traversal method applies to a restricted layout model consisting of little more than the basic layout model. The other methods are used for various extensions to the basic model. Methods 2, 3 and 4 are equivalent to solving various optimization problems.

[0494] An optimization problem consists of a set of constraints and an objective function that must be minimized or maximized. In the application **121**, some of the rules defining a layout represent constraints and some of the rules are used to define the objective function.

[0495] The simplex method is a well-known method for solving a particular class of optimization problems. The simplex method is suitable for use with some of the layout models described as part of this disclosure.

[0496] The simplex method only supports linear objective functions, whereas it is desirable to have a strictly convex function to ensure that the layout has a unique solution. Typically, a quadratic objective function is used, because there are well-known techniques for solving optimization problems with linear constraints and a quadratic objective function. The simplest of these are modifications of the simplex algorithm. These methods are well known in the art of solving optimization problems and any of these may be used without departing from scope of the present disclosure.

[0497] 16. Detailed Description of Layout Models

[0498] 16.1 Basic Layout Model

[0499] One aspect of the application **121** includes of a method of laying out a collection of items. Typically, the items are laid out in a rectangular space in accordance with a set of rules or constraints. **FIG. 22** shows an example set of items and constraints.

[0500] A basic layout model is described for defining such layouts. The basic layout model is used to define the basic structure of a layout and the limits of the variability of the layout. For example, the basic layout model is used to define basic relationships between layout items, set minimum and maximum sizes of items and to set limits on positions of items. Extensions to the basic layout model are used to provide finer control over layouts. The advantages that basic layout model has are:

[0501] 1. it can be easily understood by a layout designer in terms of physical analogies such as rigid and movable objects;

[0502] 2. it can be easily represented and manipulated via a graphical user interface;

[0503] 3. it has a simple representation in software that can be manipulated using a well defined set of operations.

[0504] In the basic layout model, as shown in **FIG. 22**, a layout comprises one or more rectangular layout items **2201**, called boxes, the layout rectangle defined by horizontal and vertical sides **2215** and **2216**, in which to place the boxes, and zero or more rules **2207**, **2211**.

[0505] Typically, the rectangular space in which the items are to be laid out represents the printable area of a page, or part of a page in a document, and each item represents a graphic image or a block of text, although in some applications of the basic layout model the layout rectangle may be absent.

[0506] The size and location of each box in the layout is defined by the positions of the four sides of its bounding rectangle. Size and location may be specified in layout units, which are typically related to an absolute unit of measurement such as millimeters. Rules **2207**, **2209**, **2211**, and **2213** define relationships between the sides of items or the layout rectangle. A rule may define a relationship between opposite sides of the same item, such as rules **2211**, **2213**, between the side of an item and the side of another item, such as rule **2209**, between the side of an item and a side of the layout rectangle **2207**, or between opposite sides of the layout rectangle, such as rule **2217**. A side, in this description, is defined to mean the left, right, top or bottom of an item or object.

[0507] In the basic layout model, the side of each box is associated with an abstract layout item called an "alignment mark" or just "mark". The sides of the layout area are also associated with marks. Thus, the basic layout model supports two kinds of layout items: boxes and marks.

[0508] The term "alignment mark" is an abstraction and generalization of registration marks used by printers to align multiple images to be printed on top of each other. There are two kinds of alignment marks: horizontal and vertical. A horizontal mark represents a vertical position on the page or layout and may be thought of as a horizontal line of indeterminate or infinite length. A vertical mark represents a horizontal position on the page and is conceptually a vertical line of indeterminate or infinite length.

[0509] Alignment marks are not generally intended to be printed—they exist purely to define positioning and relationships between boxes. Alignment marks may be displayed in various ways (or not at all) by the user interface.

[0510] A layout is associated with a two-dimensional coordinate system. It is the job of the layout engine **105** to determine the position or coordinate of each mark in the chosen coordinate system. Vertical marks have a horizontal coordinate and horizontal marks have a vertical coordinate.

The coordinate system is preferably specified by assigning coordinates to one designated vertical mark and one designated horizontal mark. The coordinates of all other marks are determined by their offsets relative to the designated marks. If the layout is of a fixed size, the marks used to specify the coordinate system are typically two sides of the layout rectangle.

[0511] A box is a rectangular area typically associated with some text or graphics. A box may be used to represent a container when calculating a layout. Each box is associated with four marks that define the sides of the box. A box is essentially a relationship between four marks. In extensions of the basic layout model additional marks may be associated with boxes. In the basic layout model, the layout rules used to determine the position and dimensions of boxes are completely described in terms of the marks associated with their sides, but in extensions of the model, additional rules are associated with boxes.

[0512] Boxes and marks are also used to represent shapes and positions that do not correspond directly to shapes and positions of objects that appear in the document. For example, boxes are also used to represent ideal dimensions of items, which may be different to the sizes calculated by the layout engine **105**. Marks may be used to define limits on the placement of other items, for example, marks may be placed at positions representing page margins and rules may be added to ensure that the layout engine **105** does not place items outside the page margins.

[0513] In the basic model, each rule represents either a vertical offset **2209** or a horizontal offset **2213** and may have either a specified size **2207** or an unknown non-negative size (shown as dashed lines) **2213**. A fixed offset rule specifies the size and direction of the vertical or horizontal offset between two marks in the layout. An unknown offset constraint specifies only the direction of the offset between two marks. For example, the offset **2211** indicates that the edge **2221** of box **2219** must always be above the edge **2223** of the same box. The size of an unknown offset constraint represents a value that needs to be calculated by the layout method.

[0514] Thus, in the basic model, there are two types of rules: fixed offset rules and non-negative offset rules. Each type of offset rule defines a constraint on the relative positions of a pair of marks.

[0515] A fixed offset rule indicates that the offset between the position of a first mark and a second mark must have a specified value. For instance, given marks m and n, a fixed offset rule is a constraint denoted by: fixed(m, n, d) defined by the equation:

$$\mathrm{pos}(n)-\mathrm{pos}(m)=d,$$

[0516] where d is a non-negative number. Struts **412** are represented as fixed offset rules in the layout engine. Also if a container has a fixed width, this is indicated to the layout engine by adding a fixed offset constraint relating the marks representing the left and right sides of the container. Similarly, if the container has a fixed height, this is represented in the layout engine by a fixed offset constraint between the marks representing the top and bottom edges of the container.

[0517] The distance d represents the offset from one mark to the other, and pos(u) denotes the position of a mark u. The position of a horizontal mark is the vertical distance of the mark from the origin of the layout coordinate system to the mark. The position of a vertical mark is the horizontal distance from the origin of the layout coordinate system to the mark. Any coordinate system may be used that is convenient for defining the layout. In a fixed offset rule, the two marks must be of the same orientation. In this regard, the marks must both be horizontal marks or they must both be vertical marks.

[0518] Note that the term "fixed" in this context refers to a value that is an input to the layout calculation method, and cannot be changed by the layout engine **105**.

[0519] A non-negative offset rule is a constraint that specifies that the offset between two marks is non-negative. A non-negative rule between a mark m and a mark n is a constraint denoted by non-negative(m, n) and defined by the inequality:

$$\mathrm{pos}(n)\geqq\mathrm{pos}(m).$$

[0520] In a non-negative offset rule, the two marks must be of the same orientation. For example, the marks must both be horizontal marks or they must both be vertical marks.

[0521] In the basic layout model, the horizontal rules are independent of the vertical constraints, so the problem of calculating the layout may be split into two separate problems. **FIG. 23** shows just the vertical offsets corresponding to the layout shown in **FIG. 22**. In this implementation, distances are specified in logical units. In **FIG. 23**, fixed offset rules have been labeled with the size of the offset in logical units. In this case it is assumed for simplicity that each logical unit corresponds to one mm. Logical units may be any convenient size for the application, but typically one logical unit would be smaller than the smallest independently addressable printer dot. The vertical offset rules shown in **FIG. 23**, may be represented in the form of a directed graph **2400** as shown in **FIG. 24**. In **FIG. 24**, each vertex **2401** represents a horizontal mark, and each arrows **2403** represent a rule. Fixed offset rules (e.g. **2402**) are shown as solid lines and non-negative offset rules (e.g. **2405**) are shown as dashed lines. In **FIG. 24**, for example, arrow **2402** between a root node **2404** and a terminal node **2406** represents the fixed offset rule **2217** from **FIGS. 23**, and which defines the height of the layout rectangle of **FIG. 22**. Further, the non-negative offset rules are variable within boundaries established by the fixed offset rules. For example, an increase in the value of h1 will cause a corresponding decrease in the value of h2 and the value of h3, both of which depend from a terminal node **2408** of h1.

[0522] Typically, the layout area is of a fixed size. This is specified by connecting the marks associated with opposite sides of the layout area with fixed offset rules. In some applications, it also makes sense for the layout engine **105** to calculate the size of the layout rectangle based on relationships between the sides of the layout area and items in the layout. Typically, rules are added to the layout to ensure that the boxes representing printable items are constrained to be within the layout area, but in some implementations, this may not apply, and the layout area rectangle may not be required. In some applications of the basic layout model, the layout rectangle may be missing.

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[0523] 16.2 Alternative Representations of the Basic Layout Model

[0524] In another implementation, the basic layout model is represented in a different, but equivalent way, to that described above. Here, the basic layout model is represented using only one type of rule: a minimum offset rule.

[0525] The minimum offset rule specifies the minimum allowed offset between a first mark and a second mark. A minimum offset rule between a mark m and a mark n is a constraint denoted by min (m, n, d) and defined by the inequality:

$$\text{pos}(n)-\text{pos}(m)\geqq d,$$

[0526] where d is a number representing the minimum allowed offset. In this representation, the number d may be positive, negative or zero, and the two marks related by a minimum offset rule must be of the same orientation (ie. both be horizontal marks or both be vertical marks).

[0527] In another equivalent implementation, maximum offset rules may be used instead of minimum offset rules. A maximum offset rule, denoted by max (m, n, d), is defined by the inequality:

$$\text{pos}(n)-\text{pos}(m)\leqq d,$$

[0528] where d is a number representing the maximum allowed offset.

[0529] To see that only one of these two types of rules is required, note that any maximum offset rule can be replaced by an equivalent minimum offset rule because of the equivalence:

$$\text{max}(m, n, d)\equiv\text{min}(n, m, -d).$$

[0530] To see that the alternative representation of the basic layout model is equivalent to the representation originally described, note that any non-negative offset rule is a special case of a minimum offset rule as seen from the equivalence:

$$\text{nonnegative}(m, n)\equiv\text{min}(m, n, 0),$$

[0531] and any fixed offset rule is equivalent to two minimum offset rules as seen by the equivalence:

$$\begin{aligned}\text{fixed}(m, n, d) &\equiv \text{min}(m, n, d) \text{ and } \text{max}(m, n, d)\\ &\equiv \text{min}(m, n, d) \text{ and } \text{min}(n, m, -d).\end{aligned}$$

[0532] Conversely, any minimum offset rule can be expressed using an extra mark t, a fixed offset rule and a non-negative offset as shown by the equivalence:

$$\begin{aligned}\text{min}(m, n, d) &\equiv \text{fixed}(m, t, d) \text{ and } \text{nonnegative}(t, n), \text{ if } d \geq 0\\ &\equiv \text{fixed}(t, m, -d) \text{ and } \text{nonnegative}(n, t), \text{ if } d < 0,\end{aligned}$$

[0533] where t is an extra mark used to mark the limit of the allowed positions of n relative to m. In the special case where d=0, t may be replaced by m, and the fixed offset rule is redundant.

[0534] Thus, there are many equivalent representations that allow minimum and maximum offsets, fixed offsets and non-negative offsets to be specified. Minimum offset rules may be used to represent all of these types of rules because this simplifies the data structure used to represent layouts, and the software for manipulating the data structure.

[0535] Directed graphs are also preferably used to represent layouts conforming to the basic layout model where each graph vertex corresponds to a mark and each graph edge is labeled with a number representing the minimum allowed offset from the mark represented by the source vertex of the edge to the mark represented by the destination vertex of the edge. Thus, for any given layout, a graph representation may be produced where each mark in the layout is represented by a corresponding vertex of the graph, and each minimum offset rule is represented by a corresponding directed edge. In the basic layout model, boxes may be ignored in the representation because each box is completely described by the marks corresponding to its sides.

[0536] There are numerous ways to represent a graph in the memory of a computer and any appropriate representation may be used. Generally it is convenient to store layouts consisting of the items and constraints in a form other than a graph representation for the purpose of displaying and editing, so typically the layout will not be always represented directly in the form of a graph in an interactive application. The graph representation may comprise means for labeling the edges and vertices of the graph with numbers and other information as required.

[0537] **FIGS. 33A** to **33**C show how the minimum and maximum height of a container may be represented using only fixed offset rules and non-negative offset rules and also using only minimum offset rules. In **FIG. 33A**, a container **3300** is shown with a minimum allowed height of 40 units and a maximum height of 100 units. The container **3300** is represented in the layout engine **105** by a box with the top edge associated with mark **3301** and bottom edge associated with mark **3303**. The directed graph of **FIG. 33B** has four vertices **3305**, **3307**, **3309** and **3311**. The vertex **3305** represents the mark **3301** and the vertex **3307** represents the mark **3303**. The other two vertices **3309** and **3311** represent extra marks that define the range of movement allowed for mark **3303** relative to the mark **3301**. The positions of these marks are fixed relative to the mark **3301** using fixed offset rules represented by solid edges **3317** in the graph. Two non-negative offset rules represented by dashed edges **3319** in the graph are used to constraint the position of the mark **3303** to be between the two extra marks **3311** and **3309**. The second directed graph of **FIG. 33C** represents the same constraints using only two vertices **3313** and **3315** where vertex **3313** represents mark **3301** and vertex **3315** represents mark **3303**. Two edges **3319** are used to represent minimum offset rules. The edge from vertex **3313** to **3315** represents a minimum offset rule with minimum value 40. The edge from vertex **3315** to **3313** represents a minimum offset rule with minimum offset −100. This is equivalent to a maximum offset rule from **3313** to **3315** with maximum value of 100.

[0538] 16.3 Shape Rules

[0539] In variable data printing applications, it is convenient to be able to define a relationship between the width and height of a box. In the basic layout model there is no way to do this.

[0540] For example, a box might correspond to an image that is to be inserted into the layout and the size of the image might need to be adjusted to fit into the available space. It is desirable in such a case, to be able to specify the aspect ratio of the box and have the layout engine **105** determine the best size of the box based on the sizes of other items in the layout. As another example, a box may correspond to the bounding box of a block of text whose height and width are not specified, so both need to be determined by the layout engine **105**.

[0541] The basic layout model may be extended to allow additional rules called shape rules that define relationships between the widths and heights of boxes, and to include two types of shape rules: aspect rules and text rules.

[0542] An aspect rule specifies that a box must have a particular aspect ratio. A text rule specifies that a box should be shaped as a bounding box for a particular block of text. Layout of text is handled by a special purpose module. Examples of text layout are described later in this document.

[0543] The behavior of shape rules is described in more detail below because their exact behavior depends on the method used to calculate layouts. These rules may have different behavior in different implementations depending on the method chosen to calculate positions and dimensions of items.

[0544] 16.4 Equal Offset Rules

[0545] Another type of constraint that is convenient to have when specifying the layout is to be able to specify that two distances are equal. This can be specified using an equal offset rule denoted by equal(m, n, s, t) for marks m, n, s and t, where m and n have the same orientation and s and t have the same orientation. The equal offset rule equal(m, n, s, t) is defined by the equation:

$$\text{offset}(m, n)=\text{offset}(s, t),$$

[0546] where offset(a, b) denotes the offset from a first mark a to a second mark b, such that

$$\text{offset}(a, b)=\text{pos}(b)-\text{pos}(a).$$

[0547] The basic layout model can be extended by the addition of equal offset rules. Allowing equal offset rules in a layout model makes it very easy to create layouts that are over-constrained.

[0548] Equal offset rules are not supported in all implementations, because equal offset rules require a more general layout method which is less efficient than that preferred in the layout engine **105**. The layout engine **105** preferably includes minimize distance rules, defined below, instead of equal offset rules as an alternative means for making various offsets equal.

[0549] 16.5 Rules Involving Centers of Boxes

[0550] In the basic layout model, only the edges of boxes participate in the layout rules. It is also desirable to be able to define relationships between the centers of boxes. In an extension to the basic layout model, each box is always associated with two additional marks. These comprise of a vertical mark and a horizontal mark that both pass through the center of the box.

[0551] In a model that allows equal offset rules, marks can be associated with the center of each box using equal offset rules, so no additions to the model are needed to support rules involving centers of boxes.

[0552] 16.6 Fixed Center Rules

[0553] As a special case of rules involving centers of boxes, in another implementation, there is an extension to the basic layout model that allows the vertical or horizontal position of the centre of each box to be fixed relative to the page or relative to a side of the page or layout area. This special case avoids the need for equal offset rules, so a simpler method of calculating layouts can be used.

[0554] A fixed center rule can be considered to be a relationship between a pair of marks associated with the opposite sides of a box, so additional marks passing through the center of the box do not need to be added to the layout.

[0555] 16.7 Maximize Offset and Minimize Offset Rules

[0556] The basic model layout rules and additional rules described so far are useful for specifying precise constraints such as exact sizes of items and spaces between items and for specifying limits on the variability of positions and sizes of items. With the rules described thus far, defining layouts that are over-constrained or under-constrained can be readily achieved. To give a finer degree of control over layouts, a good strategy is to use the basic model rules and other precise rules such as equal offset and fixed center rules to define an under-constrained layout and add additional, more flexible rules for specifying preferences for sizes and positions of items. Two additional types of rules may be used for this purpose: minimize and maximize rules.

[0557] The rules defined so far define constraints that the layout method must obey. Unlike the rules defined above, minimize and maximize rules define the objective function for the layout method.

[0558] A minimize offset rule, denoted by minimizeoffset(m, n), indicates to the layout engine **105** that the offset from mark m to mark n should be as small (ie. as negative) as possible. This behavior of this rule will be defined in detail below as it depends on the method of calculating layouts.

[0559] A maximize offset rule, denoted by maximizeoffset(m, n), indicates to the layout engine **105** that the offset from mark m to mark n should be as large (ie. as positive) as possible. This behavior of this rule will be defined in detail below as it depends on the method of calculating layouts.

[0560] The minimize offset and maximize offset rules are useful for including in linear objective functions and so may be included in layout models suitable for calculation using the simplex method. If a linear objective function is used, then each minimize rule or maximize rule contributes a linear term to the objective function. In this case only one of these two types of rules are necessary because the rule minimizeoffset(m, n) is equivalent to maximizeoffset(n, m). Therefore, the data representation of a layout model that includes these types of rules only needs to support one of

these type types of rules. For example, the data structure may only support minimize offset rules, and each maximize offset rule is represented using the equivalent minimize offset rule.

[0561] 16.8 Minimize Distance Rules

[0562] Use of maximize offset and minimize offset rules may lead to layouts where the ideal separation between two marks is infinite, so the rules do not always lead a well-defined layout. To avoid this problem, maximize offset rules and minimize offset rules may be replaced with another type of rule. Alternatively, another type of rule called a minimize distance rule, denoted by minimizedist(m, n) is used to specify that the distance. For instance, the absolute value of the offset, between two marks m and n should be as small as possible. Minimize distance rules only apply between of marks with the same orientation. In a specific implementation, another type of rule called a preferred offset rule, described below, is used instead of using minimize distance rules.

[0563] Note that a minimize distance rule can be approximated using fixed offset rules, minimize and maximize offset rules and non-negative offset rules using the following equivalence:

minimizedist(m, n)≡minimizeoffset(m, t) and minimizeoffset(n, t) and nonnegative(m, t) and nonnegative(n, t),

[0564] where t is an extra mark added to the layout and not involved in any other rules. This approximation may not be exact and depends on the exact layout calculation method used. In particular, the exact placement of items calculated by the layout method depends on the objective function chosen.

[0565] Note also that a minimize offset rule can also be approximated using a minimize distance rule using the following equivalence:

minimizeoffset(m, n)≡minimizedist(t, m) and fixed(t, n, d);

[0566] where t is an extra mark added to the layout and d is a large positive number representing a distance much larger than the largest desired distance between m and n. This approximation is not exact and the exact placement of items will depend on the exact implementation of the layout calculation method, but it proves that functionality similar to maximize and minimize offset rules can be provided by adding only minimize distance rules to any layout model that allows fixed offset and non-negative offset rules.

[0567] In some implementations, minimize distance rules may also include an extra value indicating the strength of the rule. Such a rule may be denoted as minimizeoffset(m, n, s), where m and n are the marks related by the rule and s is a positive number representing the strength of the rule. In this case, when more than one minimize distance rule affects the position of a mark, stronger rules have a greater influence over the position than weaker rules.

[0568] 16.9 Preferred Offset Rules

[0569] In a specific implementation, another type of rule, called a "preferred offset rule" is used instead of using minimize distance rules. A preferred offset rule, denoted by preferred(m, n, d), specifies that the preferred offset from mark m to mark n is d. A preferred rule can be represented by a minimize distance rule via the following equivalence:

preferred(m, n, d)≡fixed(m, t, d) and minimizedist(t, n),

[0570] where t is an extra mark added to the layout to represent the preferred position of n relative to the position of m.

[0571] Conversely a minimize distance rule can be represented using a preferred offset rule via the equivalence:

minimizedist(m, n)≡preferred(m, n, 0).

[0572] Therefore, adding either minimize distance rules or preferred offset rules to any extension of the basic layout model will result in equivalent models. The preferred offset rules are used instead of minimize distance rules because this representation typically requires less marks and less rules for commonly specified layout relationships.

[0573] The preferred offset rules may, as desired, also include an extra value indicating the strength of the rule. Such a rule may be denoted as preferred(m, n, d, s), where m and n are the marks related by the rule, d is a number representing the preferred offset from m to n and s is a positive number representing the strength of the rule. In this case, when more than one preferred offset rule affects the position of a mark, stronger rules have a greater influence over the position than weaker rules. Preferred offset rules with strengths are equivalent to minimize distance rules with strengths via the following equivalences:

preferred(m, n, d, s)≡fixed(m, t, d) and minimizedist(t, n, s),

[0574] where t is an extra mark added to the layout to represent the preferred position of n relative to the position of m, and

minimizedist(m, n, s)≡preferred(m, n, 0, s)

[0575] 16.10 Preferred Layout Model

[0576] One desirable layout model includes the basic layout model, extended to add the following types of rules defined above:

[0577] 1. rules for fixing the center of a box horizontally or vertically;

[0578] 2. shape rules to support boxes containing text and images; and

[0579] 3. preferred offset rules.

[0580] This layout model is flexible enough to support all commonly needed layout features, while being both simple enough for users to understand, simple enough to have a simple data representation and able to support a fast method for calculating positions and dimensions of layout items.

[0581] 16.11 An Example Layout

[0582] **FIG. 37A** shows how the example layout shown in **FIG. 4** is represented in one implementation of the layout engine **105** using boxes, marks and rules. The bounds of the layout area are represented by marks **3701**, **3703**, **3705** and **3707**. A layout area typically represents a part of a page in a template. The height of the layout area is represented by a fixed offset rule **3709**. The width of the layout area is represented by a fixed offset rule **3711**. The two containers shown in **FIG. 4**, are represented in the layout engine **105** by

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two boxes **3702** and **3704** shown in **FIG. 37A**. The marks **3701** and **3705** are designated as origin marks.

[**0583**] The four edges of the first box **3702** are represented by marks **3713**, **3715**, **3717** and **3719**. The top-left corner of the box **3702** has a fixed position on the page 150 logical units to the right of the left side of the layout area, and 200 units below the top of the layout area. This is represented by the two rules **3735** and **3737**. The rule **3735** ensures that the left side of the box **3702** is 150 units right of the left side of the layout area and the rule **3737** ensures that the top of the box **3702** is 200 units below the top of the layout area. The height and width of the box **3743** are not fixed and thus are calculated by the layout engine **105**. A minimum offset rule **3744** indicates that the minimum width of the box is 120 logical units. The rule **3742**, indicates that the minimum height of the box is 100 logical units. A preferred offset rule **3741** indicates to the layout engine **105** that the preferred height of the box **3702** is 550 logical units. Another preferred offset rule **3743** indicates to the layout engine **105** that the preferred width of the box **3702** is also 550 logical units. The preferred width and height of the box are determined from the content of the container that the box represents. A minimum offset rule **3739** tells the layout engine **105** that the bottom edge of the box **3702** must not be below the bottom of the layout area represented by the mark **3703**.

[**0584**] The four edges of the second box **3704** are represented by the marks **3721**, **3723**, **3725** and **3727**. The positions of the top and bottom edges of the box **3704** are fixed relative to the layout area. The position of the top edge is represented by mark **3725**. The top edge is fixed at 200 logical units below the top of the layout area by the fixed offset rule **3731**. Similarly, the bottom edge of the box is fixed at 750 logical units below the top of the layout area by the rule **3733**.

[**0585**] The width of the box **3704** is fixed at 550 logical units by the fixed offset rule **3729**, but the positions of the left and right sides of the box are not fixed and must be calculated by the layout engine **105**. The minimum offset rule **3747** indicates to the layout engine that the right edge of the box represented by mark **3723** must not extend past the right edge of the layout area represented by the mark **3707**.

[**0586**] Additional minimum offset rules **3748** and **3749** ensure that variable edges remain inside the layout area. In the example, these rules are redundant, and in some implementations, redundant rules may be removed before calculating the layout. Detecting redundant rules may be done by temporarily removing the rule and using the push operation to determine whether the rule could be violated by pushing the affected marks. If the rule cannot be violated using the push operation, then the rule is redundant.

[**0587**] The strut **412** is represented by the fixed offset rule **3745**. This rule indicates to the layout engine **105** that the distance between the two boxes **3702** and **3704** must be 200 logical units.

[**0588**] **FIG. 37B** shows the graph that represents the horizontal offset rules shown in **FIG. 37A**. Another similar graph (not illustrated) may be used to represent the vertical offset rules. The vertex **3751** represents the mark **3705** corresponding to the left edge of the layout area. The vertex **3761** represents the mark **3707** corresponding to the right edge of the layout area. The vertex **3753** represents the mark **3713** corresponding to the left edge of the box **3702**. The vertex **3755** represents the mark **3715** corresponding to the right edge of the box **3702**. The vertex **3757** represents the mark **3721** corresponding to the left edge of the box **3704**. The vertex **3759** represents the mark **3723** corresponding to the right edge of the box **3704**.

[**0589**] The fixed offset rule **3735** is represented by a pair of minimum offset rules represented by graph edges **3767** and **3769**. The minimum offset rule **3744** is represented by the graph edge **3771** and the maximum offset rule **3746** is represented by the graph edge **3773**. The fixed offset rule **3745** is represented by the graph edges **3775** and **3777**. The fixed offset rule **3729** is represented by the graph edges **3779** and **3781**. The minimum offset rule **3747** is represented by the graph edge **3783**.

[**0590**] **FIG. 37C** shows the memory structure used to store the graph shown in **FIG. 37B**. Each graph vertex is represented by a data structure e.g. **3791** containing at least the position of the mark that the vertex represents plus an adjacency list representing the edges that leave the vertex. The adjacency list consists of records, each representing one edge, containing at least a pointer, such as the pointer **3793**, to the destination vertex and the minimum allowed offset (e.g. **3794**) from the source vertex to the destination vertex. Since the sizes of the adjacency lists vary, these are stored as linked lists. The links between adjacent records are not explicitly shown in **FIG. 37C**.

[**0591**] The preferred offsets are stored in a separate graph as shown in **FIG. 37D**. Each preferred offset is represented by an edge in the graph, such as the edge **3795**. The data structure for storing the preferred offset graph is similar to the data structure used for storing minimum offset rules. Corresponding vertices in the two graphs are linked by pointers (not explicitly shown). In some implementation, extra edges are added to each graph to ensure that each edge has a reverse edge. This is to make it possible to efficiently traverse the graph in a forwards or backwards direction.

[**0592**] 17. Detailed Description of Layout Creation and Editing

[**0593**] 17.1 Basic Operations for Creating and Editing Layouts

[**0594**] The simplest approach to creating and editing layouts is to allow any kind of item to be added or removed and to allow any kind of rule allowed by the supported layout model to be added or removed. In this approach, only minimum consistency checking is required to prevent the layout data structure from becoming inconsistent when an item is removed from the layout by automatically removing any rules involving the item being removed. In this approach, there is no guarantee that it is possible to determine positions and dimensions for the items that satisfy all of the rules.

[**0595**] It is also useful to avoid layouts that contain redundant information because this can reduce the complexity of the layout so that it is simpler for the user to understand, and the process of removing redundant information can provide feedback to the user to make the layout clearer to the user. Redundant information can also increase the size of the data structures representing the layout and can slow down the layout calculations.

[0596] The directed graph structure (**FIG. 24**) described for representing layouts involving rules from the basic layout model automatically provides a means of disallowing some types of redundant information. A graph does not allow more than one directed edge with the same source and destination vertices. This prevents more than one minimum offset rule from being applied to the same offset. If there is more than one minimum offset rule between the same pair of marks (in the same order, i.e. having the same first mark and the same second mark), then one of the rules is redundant because only the rule having the most negative minimum offset value is required.

[0597] The operation for adding a minimum offset rule preferably automatically replaces any existing minimum offset rule already represented with the same source and destination vertex with the newly added rule. Alternatively, the operation of adding a minimum offset rule to an existing layout does nothing if there is already a minimum offset rule with a smaller (ie. more negative) minimum offset value for the same offset.

[0598] In a specific implementation, operations are supported for adding and removing all of the types of rules supported by the basic layout model. Those rules comprise fixed offset rules, non-negative offset rules and maximum offset rules, although these are all represented using minimum offset rules. For example, the operation of adding a fixed offset rule is implemented by adding two corresponding minimum offset rules. Operations are provided to fix or unfix the position of any mark. Fixing the position of a mark is equivalent to adding a fixed offset rule between the mark and the origin mark of the same orientation. Operations are also provided for independently fixing the horizontal or vertical position of the center of any box. Many combinations of layout creation and editing operations are also possible.

[0599] The horizontal position of the center of a box may be effectively fixed for various reasons. For example, if the horizontal positions of the two vertical sides of the box are fixed relative to the layout area, the horizontal position of the box and width are completely determined and so, the horizontal position of the center of the box is also fixed. In this case, the operation for making the horizontal position center of the box fixed relative to the layout (ie. adding a fixed center rule), may do nothing because the rule is redundant. The same applies to fixing the vertical position of the center of the box.

[0600] In one implementation, operations for adding and removing preferred offset rules and minimize distance rules are also supported. In this implementation, minimize distance rules are represented using the equivalent preferred offset rule. Preferred offset rules may be represented in a directed graph where each vertex represents a mark and each preferred offset rule is represented by an edge connecting the vertices corresponding to the marks related by the preferred offset rule. Since a directed graph only allows a single edge with the same source and destination vertices, this might seem to be inadequate to represent layouts with more than one preferred offset rule relating the same two marks, but it turns out that in a specific implementation where preferred offset rules include a strength, any two preferred offset rules relating the same two marks can be replaced by a single equivalent preferred offset rule via the equivalence:

preferred(m, n, d, s) and preferred(m, n, d', s')≡preferred(m, n, D, S),

[0601] where

$$D = \frac{sd + s'd'}{s + s'}, \text{ and}$$

$$S = s + s'.$$

[0602] This equivalence is valid when the preferred layout calculation is performed.

[0603] 17.2 Example Based Layout Creation and Editing

[0604] When creating and editing layouts, it is desirable to avoid creating over-constrained layouts because such layouts are not useful for producing documents. The process of avoiding conflicting rules can also provide feedback to the user to improve the user's understanding of the layout being created. Avoiding inconsistent rules during creation of the layout can also reduce the amount of work involved for the user by automatically preventing mistakes.

[0605] Example based editing may be used in certain implementations to avoid over-constrained layouts. Example based editing is where the operations for creating and editing layouts are always operating on an example of the layout that obeys all constraints. Note that minimize offset rules, maximize offset rules, minimize distance rules and preferred offset rules do not impose constraints on the layout and can be ignored for the purpose of avoiding over-constrained layouts. In a variable data printing application, this might be done by allowing the user to build an example layout showing a preview of a document. The preview might be a display of one of the documents resulting from combining actual data with the document template, or the preview may contain sample data that is only similar to data expected to be inserted into the document template, or alternatively, only the sizes and positions of items might be approximately the same as expected in the actual documents to be produced from the template.

[0606] The positions and dimensions of newly created items are preferably specified when items are created, so example positions of items are always known. To store these values, each vertex of the graph used to represent the layout is labeled with the position of the corresponding mark. In addition, rules may only be added if they do not conflict with the current positions and dimensions of the items. For example, a minimum offset rule may only be added to the layout if the current positions of the marks involved obey the minimum offset rule. Similarly, when a fixed offset rule is added, the offset value must be equal to the offset between the marks related by the rule. When the horizontal or vertical position of center of a box is fixed, the position and dimensions of the box are known and the horizontal or vertical center is fixed, based on the actual position of the center of the box at the time the operation of adding the rule is performed.

[0607] The user may indicate, via the interface **103**, a change to the layout that may require rules to be added to the layout. If the example layout indicated by the user does not

satisfy the rules to be added, the layout is automatically adjusted, if possible, so that the newly added rules are consistent with the layout. For example, when the user changes the width of a fixed width container, either via a dialog box or by dragging an edge of the box, the positions of the items are modified and the rules are updated as well. This may require several layout operations such as removing some existing rules, changing the positions of the marks involved, and adding new rules. For example, when changing positions of marks, the application **121** will first remove any rules that would be violated if the position of the marks were to be changed, update the position of the marks and add new rules that are consistent with the new positions of the marks.

[**0608**] When editing or creating layouts, it is sometimes necessary to move a mark or more than one mark relative to another mark or relative to the layout origin without violating any constraints. This can be quite a complex operation if the marks to be moved are affected by numerous constraints. The layout engine **105** desirably provides an operation called "push" that moves a set of marks a given distance either horizontally or vertically without violating any constraints and also moves other marks not in the original set if necessary to achieve the requested result.

[**0609**] 17.3 The Push Operation

[**0610**] The push operation is implemented by the layout engine **105** in response to input from the user interface **103** to move a set of marks a given distance either horizontally or vertically without violating any constraints and also moves other marks not in the original set, if necessary, to achieve the requested result.

[**0611**] The push operation operates on a set of marks all of the same orientation, and may be described in terms of a graph, called the push graph. Given an example layout defined by a collection of marks and minimum offset rules together with positions assigned to each mark in the layout, a corresponding push graph may be defined. The push graph is a directed graph where each vertex corresponds to a mark in the layout, and each edge corresponds to a minimum offset rule where the actual offset is equal to the minimum value allowed by the minimum offset rule.

[**0612**] The push graph for a layout is a directed graph whose edges indicate which marks can directly push others of the marks forming the layout. A first mark can directly push a second mark (in a positive direction) if increasing the value of the coordinate of the first mark would result in violating a minimum offset rule between the first and second marks, this being when the offset between them is already at the minimum allowed. Note that it is assumed that all basic model rules have been replaced with equivalent minimum offset rules when creating or editing the layout.

[**0613**] When moving a mark in a positive direction (ie. increasing its coordinate value), any marks corresponding to vertices reachable from its corresponding vertex in the push graph must also be moved by the same distance to avoid violating any minimum offset rules.

[**0614**] When moving a mark in a negative direction (ie. decreasing its coordinate value), any marks reachable from its corresponding vertex in the reverse of the push graph must also be moved by the same distance and direction to avoid violating any minimum offset rules. The reverse of the push graph is the same as the push graph except the directions of the edges are reversed.

[**0615**] A variety of methods of determining reachable vertices in a directed graph may be used to implement the above.

[**0616**] The push operation works by moving groups of marks without violating any minimum offset rules. To calculate the range of allowed movement for a group of marks, a quantity called the "slack" is defined for each minimum offset rule. Given any minimum offset rule min(m, n, d), then the slack for the rule is given by offset(m, n)−d. The slack is the maximum distance that mark m can be moved (in a positive direction) before the rule is violated, and is also the maximum distance that mark n can be moved in a negative direction (i.e. the maximum amount by which the coordinates can be decremented) before the rule is violated. The slack for a minimum offset rule is always a non-negative number if the rule is not violated in the example layout. Each edge in the push graph corresponds to a rule with a slack of 0.

[**0617**] The maximum positive allowed movement, for a set of marks is the minimum of the slack values of all minimum offset rules min(m, n, d), where m is in the set and n is not in the set. This is the maximum distance by which the marks can be moved in a positive direction without moving any other marks not in the set and without violating any minimum offset rules. The maximum distance by which a set of marks can be moved in a negative direction can be similarly defined as the minimum of the slack values of all minimum offset rules of the form min(n, m, d), where m is in the set and n is not in the set. If there are no minimum offset rules limiting the movement of a set of marks in a given direction, then the maximum distance is infinity (ie. there is no limit on how far the marks can be moved).

[**0618**] The push operation keeps track of a current set of marks to be moved, and a distance to push which is the remaining distance that it must push the marks in the current set. The set of marks and the distance to push are updated as the steps in the operation are performed. The push operation moves the marks in one or more increments. The distance of the move in each increment is determined from the maximum allowed movement of the current set of marks. Additional marks that can be pushed by the marks in the set are added to the set before each increment, so a different set of marks is moved at each increment.

[**0619**] **FIG. 25** shows a method **2500** involved in a first implementation of the push operation. The push operation starts at step **2501** where the origin for the layout is saved. Since the push operation can change the position of the mark that defines the coordinate system, this mark and its position are remembered so that the coordinate system can be restored later in step **2513**. After step **2501**, the push operation continues to step **2502**, where the remaining distance to push is compared with 0. If the remaining distance to push is 0, there is nothing to be performed and the operation proceeds to step **2513** where the origin of the coordinate system is restored. This is done by moving all marks in the layout by an appropriate value to restore the original position of the origin mark that was saved in step **2501**. If the distance to push tested in step **2502** is not 0, the operation proceeds to step **2503**, where the push graph is updated based on the current positions of the marks in the

layout. The operation then proceeds to step **2505**. In step **2505**, the set of marks to be moved is updated by adding any additional marks that can be pushed in the push direction by any mark in the current set. For instance, any mark whose corresponding vertex is reachable in the push graph (or the reverse of the push graph if the distance to move is negative) from a vertex corresponding to any mark in the current set is added to the current set of marks. The operation continues to step **2507** where the distance for the current increment is calculated. The distance for the increment is the smaller of the remaining push distance and the maximum allowed move distance for the current set of marks in the given direction. This distance is always positive if the push distance is positive. After the distance to move is calculated, the operation continues on the set **2509**, where all marks in the current set are moved by the distance calculated in step **2507**. After step **2509**, the operation proceeds to step **2511**, where the remaining push distance is calculated by subtracting the distance moved from it. After step **2511**, the operation returns to step **2502**, where the distance calculated in step **2511** is tested to determine if another iteration if required.

[**0620**] The version of the push operation described in **FIG. 25** can never fail, but if the origin mark is moved during the operation, the behavior of the operation is unintuitive. For example, if a group of marks is pushed to the right, instead of the marks moving to the right, other marks might move to the left instead. This behavior is caused by step **2513**, restoring the origin. In practice, this behavior is sometimes useful. For example, to make a box wider by 10 distance units, pushing the right edge of the box 10 units to the right will make the box wider by 10 units if it is possible to do so, even if the right edge cannot be moved by as much as 10 units. In this regard, if the right edge can only move 3 units to the right, but the left edge can move 7 units to the left, the push operation will automatically move the left edge to the left. The side effect is that other items may also move.

[**0621**] It is also useful to have another version of the push operation that does not move origin marks. This is described in **FIG. 26** by a method **2600**. This implementation of the push operation proceeds in the same way except that steps **2501** and **2513** are omitted because they are redundant, but includes an additional test, step **2606**, that is inserted between steps **2505** and **2507**. The test of step **2606** determines if the current set of marks contains the origin mark. If so, the operation stops and fails because the marks could not be pushed as far as requested without moving the origin mark.

[**0622**] **FIGS. 27A and 27B**, **27**C and **27**D, and **27**E and **27**F together give an example of how the push operation works. These figures show a layout formed of two containers, a variable width container **2701** with minimum width 15 units and a fixed width container **2704** with width 20 units. The container **2701** is represented by a box with left and right sides associated with marks A and B. The container **2704** is represented by a box with left and right sides represented by marks C and D. These figures also show the edge of the page **2707** represented by a mark E.

[**0623**] **FIG. 27A** shows the initial state of a layout before the push operation has started. Item **2701** has a minimum width of 15 units represented by the minimum offset rule **2702**. Item **2704** has a fixed width of 20 units represented by the fixed offset rule **2705**. The two items **2701** and **2704** are connected by a strut of length 6 layout units represented by a fixed offset rule **2703**. There is an additional minimum offset rule **2706** between item **2704** and the edge of the page **2707** represented by the mark E with minimum length 15 units. This rule prevents item **2704** from getting closer than 15 units to the edge of the page. The actual distance is 20 units before invoking the push operation. The steps of the push operation are illustrated for pushing mark A 15 units to the right. A push graph **2709** for the layout is also shown in **FIG. 27B**. The graph **2709** shows the vertices representing marks B and C connected by edges in both directions because of the fixed offset rule **2703**. The vertices representing B and C are also connected in both directions because of the fixed offset rule **2705**.

[**0624**] **FIG. 27C** shows the result of the first iteration of the loop. In the first iteration, at step **2503**, the push graph **2709** is calculated. At step **2505** it is determined from the push graph that mark A does not push any other marks and can move by itself. In step **2507**, it is determined that the maximum distance that mark A can be moved without violating the minimum offset rule **2702** is 3 units. Since this is less than the requested distance, mark A is moved 3 units in step **2509** resulting in the layout shown in **FIG. 27B**. The remaining distance calculated in step **2511** is now 12 units. In the second iteration of the loop, at step **2503**, the push graph **2711** shown in **FIG. 27D** is calculated. In this graph mark A now pushes mark B, because the slack in rule **2702** is now zero, and consequently mark A also pushes marks C and D.

[**0625**] **FIG. 27E** shows the result of the second iteration of the loop where it is determined that marks B, C and D are now all pushed by mark A, so all four marks must be moved together. At step **2507**, it is determined that marks A, B C and D can be moved a maximum distance of 5 units without violating the second minimum offset rule **2706** between mark D and the edge of the page **2707** represented by mark E. The remaining distance is 12 units, but mark D can only move 5 units, so marks A, B, C and D are each moved 5 units. In step **2511**, the remaining distance is calculated at 7 units. In the third iteration of the loop, in step **2503**, the push graph **2713** shown in **FIG. 27F** is calculated. In this graph all marks now are pushed by mark A.

[**0626**] In the second version of the push operation shown in **FIG. 26**, the test **2606** determines that the origin mark E is included in the set of marks to move, so the operation stops. In the first version of the push operation shown in **FIG. 25**, the third iteration of the loop results in all marks being moved by the remaining 7 units in step **2509**, and in the following step **2511**, the remaining distance is now calculated as zero, so the test in step **2502** causes the process to go to step **2513** where the position of the origin mark E is restored by moving all marks to case, the left by 7 units. In this example, both version of the push operation, produce the same result. In is example, mark A could only be pushed a total of 8 units instead of the requested 15 units.

[**0627**] 17.4 The Push Operation with Fixed Centers

[**0628**] In layout models incorporating fixed center rules, the push operation needs to be modified to be aware of fixed centers. If the horizontal position of the center of a box is fixed, then the left and right sides of the box must always be moved in opposite directions by equal amounts, such marks

are said to be "opposed" to each other, or are said to be "opposing" marks. Similarly, if the vertical position of the center of a box is fixed, then the top and bottom sides of the box must always be moved in opposite directions by equal amounts.

[0629] To adapt the push operation to incorporate fixed centers, the set of marks to be pushed is replaced by two sets of marks. One set of marks, the forward set, is pushed in a positive direction and the other set of marks, the opposing set, is pushed in a negative direction. In step **2505**, marks are added to each of the two sets of marks as follows. If a mark is opposed to a mark contained in one of the two sets, the opposing mark is added to the other set as well as any marks that are pushed by the opposing mark.

[0630] **FIG. 32** shows in more detail a method **3200** of how the two sets of marks are determined when fixed center rules are allowed, such as used in step **2505**. In **FIG. 32**, it is assumed that the initial set of marks to push are vertical marks and that they are being pushed to the right and it is assumed that the coordinate system is increasing to the right. Pushing marks in other directions and orientations is performed similarly. In step **3201**, all marks pushed by the current set of marks are added to the forward set (ignoring fixed center rules). Step **3201** may be calculated using the push graph, by finding all vertices reachable from the set of vertices representing the forward set of marks. In addition, if any two opposing marks are included in the forward set, then the origin mark is also added to the set. Following step **3201**, in step **3203**, all marks opposing any mark in the current set are added to the set of opposing marks. In addition, if any two opposing marks are included in the opposing set, then the origin mark is also added to the opposing set. Adding the origin mark to either set effectively causes the push operation to terminate after the test in step **2606**. Following step **3203**, in step **3205**, all marks pushed to the left by marks in the opposing set are added to the opposing set. This is done in the same way as in step **3201**, except the reverse of the push graph is used because the marks are being pushed in a negative direction (ie. their coordinates are being decreased). Following step **3205**, in step **3207**, any marks that oppose marks in the opposing set are added to the forward set. Step **3207** is the converse of step **3203**. Following step **3207**, in step **3209**, a test is performed to check if new marks were added to the forward set in step **3207**. If so, the calculation returns to step **3201** so that steps **3201**, **3203**, **3205** and **3207** will be repeated until no more new marks are added to either of the two sets.

[0631] In step **2507**, the move distance is calculated independently for the two sets and the smaller of the two distances (ie. smaller in magnitude) becomes the distance to move. In step **2509**, the marks are moved the same distance but in opposite directions. The marks in one set are moved in a positive direction and the marks in the other set are moved in a negative direction.

[0632] 17.5 The Push Operation with Shape Rules

[0633] Since shape rules relate horizontal and vertical marks, adapting the push operation to incorporate layout models with shape rules is potentially complicated. The problem is that when pushing marks, complex interactions between marks of the same orientation may result from combinations of shape rules and other rules. In particular, it is possible to create circular dependencies that have no single solution. To avoid this problem, a restriction is placed on the layout model that shape rules are only applied to boxes where at most one mark corresponding to a vertical side and at most one mark corresponding to a horizontal side appears in a minimum offset rule. That is, at least one of each pair of opposite sides of a shape rule box must be free of minimum offset rules. This restriction prevents any complex relationships between marks due to shape rules. With this restriction, the push algorithm may be modified so that shape rules are applied whenever any side of a box involving a shape rule is moved in step **2509**. The shape rules are applied by moving the free edges of the box, where a free edge is an edge that is not involved in any minimum offset rules.

[0634] 17.6 Using the Push Operation for Editing Document Templates

[0635] The GUI **301** uses the push operation to modify an example layout while the user is editing a document template. **FIG. 34** shows an example method **3400** of how the GUI **301** allows the user to move a fixed edge of a container. At step **3401**, the user indicates that the edge should be moved, for example by selecting and dragging the edge with the mouse **133** and pointer **313**. Following step **3401**, at step **3402**, the application **103** unfixes the position of the mark corresponding to the edge being moved. The position of an edge is typically made fixed by adding a fixed offset rule that fixes the offset between the mark representing the edge and the origin mark with the same orientation as the edge. To unfix the edge, the fixed offset rule is removed to allow the position of the edge to be changed. Following step **3402**, at step **3403**, extra constraints are added to the layout engine **105** to limit the allowed positions of the edge. When an edge is fixed, the edge cannot be moved, so there is no need for any additional constraints on the movement of the edge. However, when the layout engine **105** is used to change the position of an edge, typically the range of movement of the edge is restricted. For example, the layout engine **105** may be told that the edge cannot be moved past the edges of the layout area. As a further example, if the edge is the left edge of a container, a non-negative offset constraint may be added between the mark representing the left edge of the layout rectangle and the mark representing the edge of the container. Also, the minimum and maximum width of the container should be enforced. The document template may be used to store a minimum and a maximum width and a minimum and maximum height for each container independently of the layout engine **105**. By adding a minimum offset constraint and a maximum offset constraint between the marks representing the left and right edges of the container, the minimum and maximum width settings of the container can be enforced by the layout engine **105** while the user is dragging the edge of the container.

[0636] Following step **3403**, the application **121** invokes the push operation to move the edge in step **3405**. The push operation ensures that the movement of the edge does not cause any constraints to be violated, and limits the movement to the range allowed by the layout rules. Following the push operation, in step **3407**, the constraints added in step **3403** are removed, and then in step **3411**, the position of the edge is fixed at the new position. After step **3411**, the application **121** uses the layout engine **105** to recalculate the layout in step **3413** as described below and shown in **FIGS. 28, 29, 30**A and **30**B. Step **3413** ensures that all of the minimize distance rules and preferred offset rules are

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applied. Step **3411** is necessary to prevent the layout engine **105** from moving the edge to another location when step **3413** is performed. Lastly, after the layout has been recalculated in step **3413**, the application **121** updates the display **144** to show the result of changing the position of the edge, and the update is complete. The steps in **FIG. 34** may be repeated as the user drags the edge of a container with the mouse to provide immediate feedback while dragging.

[**0637**] **FIG. 35** show another method **3500** of how the push operation may be used to edit document templates. The method **3500** starts at step **3501**, where the user requests a change to the width of a fixed width container. It is assumed that the position of the container is variable and the left and right edges are not fixed. This may be done by typing a new width using the keyboard **132** into a properties dialog displayed by the GUI **301**. In one implementation, clicking on the container using the right button of the mouse **133** causes a context menu, similar to the palette **311**, to be displayed. A "Properties . . . " icon may then be selected from the context menu to cause a properties dialog to be displayed. After step **3501**, in step **3503**, the difference between the current width of the container and the new width is calculated. After step **3503**, at step **3505**, the width of the container is changed from being fixed to unfixed. The width of a container is made fixed by adding a fixed offset rule between the marks representing the left and right edges of the container. As such, step **3505** comprises of removing the fixed offset rule. After step **3505**, at step **3507**, constraints are added to the layout to limit the movement of the sides of the container. The minimum and maximum width of each container may be in the document template. These restrictions are enforced by adding rules to the layout. The minimum value is enforced by adding a minimum offset rule relating the marks representing the left and right sides of the container, and the maximum value is enforced by adding a maximum offset rule relating the marks representing the left and right sides of the container.

[**0638**] Step **3509** follows step **3507**. In step **3509**, the push operation is used to move the mark corresponding to the right edge of the container to the right by the difference in width. If the change in width is negative, representative of the user requesting a smaller width, then the mark will be pushed a negative distance—therefore being pushed to the left instead of to the right. In the next step **3511**, the remaining required change in width is calculated. If the push operation in step **3509** was successful in pushing the right edge by the calculated distance, the width of the container will have changed to the correct size and the remaining distance would be zero. If the push operation in step **3509** was not successful, the current width will not be equal to the requested width and the remaining distance would be non-zero. Following step **3511**, in step **3513**, the left edge is pushed to the left using the push operation by the remaining change in size calculated in step **3511**. If the remaining change in width is negative, the left edge would be pushed to the left by a negative distance. That is, the edge would be pushed to the right.

[**0639**] If step **3513** was successful in pushing the left edge by the distance calculated in step **3511**, the width will now be equal to the requested width. If not, the width will be as close as possible to the requested width. After step **3513**, the constraints added in step **3507** are removed at step **3515** and the width is fixed at the new width at step **3517** by adding a fixed offset constraint relating the marks representing the left and right edges of the container. Following step **3517**, the layout is recalculated at step **3519** and the display is updated to reflect the newly calculated layout at step **3521**, thus completing the operation of changing the width of the container. The process of calculating layouts is explained in more detail below. In the example shown in **FIG. 35**, it is assumed that the second version of the push operation outlined in **FIG. 26** is used. If the version outlined in **FIG. 25** is used steps **3511** and **3513** would be unnecessary.

[**0640**] 18. Detailed Description of Layout Calculation

[**0641**] 18.1 Calculating Layouts Using the Simplex Algorithm

[**0642**] In one implementation, the allowed rules are those of the basic model, together with equal offset rules, aspect rules, minimize offset rules and maximize offset rules. Here, the basic model rules are equivalent to linear inequality constraints and the equal offset rules are linear constraints and the minimum offset rules and maximum offset rules are used to define a linear objective function. In this model, the rules define a linear program, so the layout calculation can be preformed using the simplex algorithm or any other method of solving linear programs.

[**0643**] In this implementation, the objective function is calculated by adding together each offset between a pair of marks related by a minimize offset rule and subtracting, from this sum, each offset between a pair of marks related by a maximize offset rule. If the rules have strengths, the offsets are first multiplied by the strength of the corresponding rule before adding or subtracting.

[**0644**] Unfortunately, there is no known way to include text rules in models whose layouts can be calculated using the simplex method without significant modification to the simplex method.

[**0645**] 18.2 Modified Simplex Method

[**0646**] In another implementation, the allowed rules are those of the basic model, plus equal offset rules, aspect rules, minimize distance rules and preferred offset rules. In this implementation, the minimum offset rules and equal offset rules are converted into linear constraints and the minimize distance rules and preferred offset rules are used to define a quadratic objective function. In this model, the constraints are either linear equalities or linear inequalities and the objective function is a quadratic function. These types of problems may be solved using methods known to those skilled in the art of quadratic optimization. A modified version of the simplex method may by used to calculate layouts in this model.

[**0647**] As with the simplex method, there is no known way handle models that allow text boxes with variable width and height using quadratic programming, without significant modification to the quadratic programming.

[**0648**] 18.3 Graph Based Layout Calculation

[**0649**] In another implementation, the layout model used allows all of the basic model rules, preferred offset rules and shape rules. This model is the same as the preferred layout model except that fixed center rules are not allowed. In this implementation, the basic model rules are represented using minimum offset rules and these are stored as a directed

graph. Preferred offset rules are stored as a separate directed graph. Shape rules are stored separately. This method has the advantage over the simplex and quadratic programming methods that it incorporates both aspect rules and text rules, and can be modified to incorporate other shape rules as well.

[0650] Further, in this implementation, each container is associated with a box. For some containers, a further separate box may be associated with the container and used to represent the ideal size and/or shape of the container. Minimize offset rules are used to tell the layout engine **105** to make the box representing the printed or displayed shape of the container as close as possible to the size and shape of the box representing the ideal shape. The ideal size and shape of the container is defined by applying a shape rule to the associated box. The layout calculation method operates to make the size and shape of the container as close as possible to the ideal size and shape. It is not always possible to make the container exactly the ideal size and shape because at its ideal size and shape it might not fit in the available space in the layout. For example, constraints may prevent it from being the ideal size or shape.

[0651] The minimum offset rules are used to define constraints that limit the possible positions of the marks, the preferred offset rules are used to define an objective function that is minimized by the layout calculation method, and the shape rules are used to dynamically guide the calculation method. To define the objective function, each preferred offset rule is associated with an energy value. The energy of a preferred offset rule is half of the square of the difference between the preferred offset and the actual offset. The objective function, called the total energy, is the sum of the energies of all of all of the preferred offset rules. If strengths are assigned to preferred offset rules, then the energy is multiplied by the strength. A preferred offset rule may be thought of as a spring that has a natural length and is under tension if compressed or stretched. The tension of a preferred offset rule is the strength of the rule multiplied by the difference between the actual offset and the preferred offset. The strength of the rule is analogous to the stiffness of the spring. The layout engine **105** calculates the layout by minimizing the total energy by balancing the tensions of all of the preferred offset rules.

[0652] **FIG. 28** shows the main steps involved in calculating the layout. The layout calculation method **2800** moves (ie. changes the positions of) marks without violating any of the minimum offset rules until the total energy is minimized. The method **2800** starts at step **2801**, where the layout engine **105** searches for a group of marks that can be moved to reduce the value of the objective function without violating any basic model rules. At step **2803**, a test is performed to test if the search was successful, if so, the method proceeds to step **2805**, otherwise the layout calculation is complete and the method **2800** stops. At step **2805**, the marks are moved a suitable distance in a suitable direction to reduce the total energy. After step **2805**, the method **2800** returns to step **2801**, where it searches for another group of marks to move. Methods of selecting groups of marks to move and methods of calculating the distance to move the marks are described in more detail below. To ensure that the process described in **FIG. 28** terminates, small changes in positions of marks and/or changes in positions of marks that result in small changes in total energy are ignored. In one implementation, the changes in position may be restricted to a whole number of logical units.

[0653] **FIG. 29** shows an equivalent procedure **2900** to that shown in **FIG. 28** except that vertical marks are moved first (step) before any groups of horizontal marks are moved (step **2903**). The test at step **2905** serves the same purpose as the test at step **2803**. There are many possible ways to organize the method of reducing the total energy without departing from the scope of the present disclosure.

[0654] **FIG. 30A** shows in more detail how step **2901** may be performed in one implementation as step **2901**-A. In step **3001**, the push graph for the vertical marks is calculated. This is used to determine which marks can be pushed by a given mark. In some implementations, this graph may be a separate data structure from the graph representing the rules. In other implementations, the two data structures may be combined. In step **3003**, the first vertical mark is retrieved by retrieving the first vertex from the graph representing the vertical marks and horizontal minimum offset rules. There are many possible orders in which the marks may be retrieved. In one implementation, the marks may be retrieved in the order that their corresponding vertices are stored in the graph that represents the horizontal minimum offset rules. After step **3003**, the method proceeds to step **3005**, where the marks that can be pushed to the right by the mark chosen in step **3003** are calculated. Step **3005** determines a group of marks that can all be moved to the right by some non-zero distance without violating any minimum offset rules. The group is comprised of the mark chosen in step **3003** plus all marks that can be pushed by the chosen mark (ie. all marks corresponding to vertices that are reachable in the push graph from the vertex corresponding to the chosen mark). Step **3007** determines the maximum distance that the group of marks determined in step **3005** can be moved to the right without violating any minimum offset rules. The calculation in step **3007** is the same as that performed as part of step **2507** of the push operation. After step **3007**, step **3009** calculates the distance that the marks in the group should be moved to reduce the total energy, this not being greater than the distance calculated in step **3007**. Step **3009** will be described in more detail below. The distances moved may be restricted to a whole number of logical units. After step **3009**, the method proceeds to step **3011** where the marks are moved by the distance calculated in step **3009**. Since the marks may have changed position, the push graph may need to be updated to reflect the consequences of the new positions. If the distance calculated in step **3009** is equal to the maximum allowed distance calculated in step **3007**, the push graph will need to be changed. This is done in step **3013** that follows step **3011**. It is also possible that moving the marks to the right would not decrease the total energy. In this case, the distance calculated in step **3009** would be 0 and the marks would not actually change position in step **3011**. Steps **3011** and **3013** would then both effectively do nothing, and may be skipped in some implementations. Steps **3015**, **3017**, **3019**, **3021** and **3023** are equivalent to steps **3005**, **3007**, **3009**, **3011** and **3013** respectively, except that the direction of movement is reversed. In these steps, the reverse of the push graph is used instead of the push graph. One skilled in the art of software engineering will understand that it is possible to design the directed graph data structure used for the push graph so that the same push graph can be traversed in a reverse direction, so a separate reversed push graph is not needed. After step

3023, a test is performed to determine if all vertices have been visited at step **3003**, if not, the method returns to step **3003** where the next mark is selected. If so, step **2901** is complete and the calculation proceeds to step **2903**.

[**0655**] Step **2903** is the same as step **2901** except that the horizontal marks and vertical minimum offset rules are considered instead of vertical marks and horizontal minimum offset rules.

[**0656**] **FIG. 31** shows the details of how the calculation in step **3009** is performed. In step **3101**, the partial derivative of the total energy is calculated with respect to a change in position of the current set of marks from their current positions. The derivative of the total energy is equal to the sum of the tensions. The partial derivative is equal to the sum of the tensions of the preferred offset rules relating marks in the current set to marks not in the current set. That is, the sum is over rules of the form preferred(n, m, d, s), where m is a mark in the current set and n is a mark not in the current set. Note that the rule preferred(m, n, d, s) is equivalent to the rule preferred(n, m, –d, s), for any marks m and n. The energy is minimized by making the sum of the tensions as close to zero as possible. This is accomplished in step **3103** by moving the marks a distance δ given by:

$$\delta=-D/S,$$

[**0657**] where D is the sum of the tensions and S is the sum of the strengths of the preferred offset rules relating marks in the current set to marks not in the current set. In step **3105**, a test is performed to determine if the objective function is decreasing in the direction of movement being considered for the current set of marks. This is equivalent to testing is δ is positive. If the energy cannot be decreased by moving the marks in the current direction, then the distance to move is set to zero in step **3107**. If the energy can be decreased by moving the marks in the current direction, then the distance to move is calculated in step **3109**. The distance to move is the smaller of δ and the value calculated in step **3007**. The movement of marks may be restricted to whole multiples of logical units, so the distance calculated in step **3007** is rounded to whole logical units. This guarantees termination of the layout calculation.

[**0658**] The same considerations about the origin marks apply to the layout calculation as apply to the push operation described above. In this regard, the origin marks may be ignored by the layout calculation in which case step **3005** will always find a set of marks that can be moved except that the designated vertical mark that defines the origin of the horizontal coordinate system may be contained in the set of marks to be moved. In this case, step **3007** will always produce a non-zero positive distance and step **3011** may change the position of the origin mark. In this case, the position of the origin mark should be stored before step **3001** and the position of the origin mark should be restored by moving all vertical marks in the layout by minus the distance that the origin mark has been moved during the calculation. In another implementation, the origin marks are considered in step **3007**. In this regard, if an origin mark is included in the set of marks to be moved, then the distance calculated in step **3007** is 0. In this case, the origin does not have to be saved or restored when performing the layout calculation.

[**0659**] Shape rules need only used for containers that have both unfixed width and unfixed height. For such a container, the part of the container that contains the content is represented in the layout engine **105** by two boxes. One box represents the boundary of the displayed or printed text or image contained in the container. The boundary of this box is calculated by the layout engine. The other box represents the ideal shape of the box. This box is controlled by a shape rule and is typically not printed or displayed to the user. The two boxes share one horizontal mark and one vertical mark. For example, the positions of the left and top edges of the two boxes are always equal. It makes no difference whether the left or right edges are shared or whether the top or bottom edges are shared. The remaining two vertical edges are related by a minimize distance rule, and similarly, the remaining two horizontal edges are related by a minimize distance rule. The minimize distance rules indicate to the layout engine that the two boxes should be made as close to each other in size as possible.

[**0660**] Shape rules are taken into account when moving any mark associated with an edge of either box of such a pair of related boxes. The marks belonging to the boxes with shape rules that are not shared may be ignored and skipped in step **3003**, but these unshared marks are adjusted before step **3009** if any of the marks representing an edge of the associated box without the shape rule are to be moved. The same applies to the equivalent steps applied to the horizontal marks. The unshared marks are adjusted in accordance with the shape rule to minimize the energy function. This process ensures that the energy is balanced between the vertical and horizontal marks.

[**0661**] In the case where the shape rule is an aspect rule, it is straightforward to minimize the energy. If the width and height of the display box are W and H and the width and height of the ideal box are w and h, then the minimum energy is achieved when W+H=w+h. If the ratio of height to width defined by the aspect rule is r, then the width and height of the ideal box can be calculated as:

$$w=(1+r)^{-1}(W+H) \text{ and } h=r(1+r)^{-1}(W+H).$$

[**0662**] In the case where the shape rule is a text rule, there is no simple formula for the shape of the ideal box. The text layout engine performs calculations to lay out text inside a rectangular space. The text layout engine is used to calculate the dimensions for the ideal box. The text layout engine performs calculations to lay out a block of text in a space with a given width, and it can rapidly calculate the height of the laid out block of text. The text layout engine incorporates word-wrap calculations to wrap long lines of text into multiple lines. The text layout engine lays out text in accordance with formatting information associated with the text. The formatting information may include the paragraph style, size of the font and the style, such as bold or underlined for example, to use for each character.

[**0663**] In one implementation, the ideal width is set to the width of the widest line of text and the ideal height is set to the height of the laid out text block calculated by the text layout engine with the width equal to the width of the display box. This has the effect of adding an energy penalty if the width is less than the width of the longest line or the display box is not high enough to contain the text.

[**0664**] In another implementation, the text layout engine is used to lay out the text at different widths calculating the height for each width until the width is found that results in

the lowest energy value. In the case where the widest line of text is not as wide as the display box, the ideal height may be set to the width of the widest line of text and the ideal height may be set to the height calculated by the layout engine when there is no wrapping of lines. Where the text contains long lines of text that must be wrapped to fit inside the display box, a search strategy is employed to find a width that results in the layout with the least energy. Many possible strategies may be devised for searching for the ideal width without departing from the scope of the present disclosure. In particular, a binary search strategy may be employed.

[0665] In another implementation, if the text contains long lines of text that must be wrapped to fit into the display box, the dimensions of the ideal box are calculated based on whether or not the text can be laid out to fit inside the display box. If the text does not fit inside the display box, the ideal box is made larger in both width and height than the display box. If the text fits inside the display box, then the ideal box is made smaller in both width and height than the display box. This strategy has the effect of adding a penalty for layouts in which the display box is larger or smaller than necessary to contain the text. There are many possible ways to calculate the exact dimensions of the ideal box without departing from the scope of the present disclosure. One particular method that may be used is to first calculate the height of the text if laid out with width equal to the current width of the display box, and then add half of the difference between the height of the laid out text and the height of the display box to both the width and height of the display box to obtain the dimensions of the ideal box.

[0666] 18.3.1 Simple One-dimensional Layout Example

[0667] **FIG. 39** shows an example usage of the layout mechanism described in Section 18.3 and later. Three boxes **3901** have been specified, A, B, and C. Each box **3901** is defined by marks **3905** at the left, top, right and bottom edges. Left and right edges of the page are defined as two vertical marks (**3903** and **3904**) with a fixed distance between those marks. There are fixed-offset rules **3902** which specify distances between some of the containers' edges and the edges of the page.

[0668] The rules in detail are:

[0669] The width of the page is fixed at 50 units.

[0670] P_A, the preferred width of container A, is 22 units.

[0671] P_B, the preferred width of container B, is 16 units.

[0672] P_C, the preferred width of container C, is 13 units.

[0673] The left edge of box A (named 'a' in **FIG. 39**) is 1 unit from the page's left.

[0674] The right edge of box A (named 'm') is free to move.

[0675] The left edge of box B (named 'b') is 6 units right of 'a'.

[0676] The right edge of box B is 1 unit left of 'm'.

[0677] The left edge of box C is 2 units right of 'm'.

[0678] The right edge of box C (named 'c') is 1 unit left of the page's right edge.

[0679] Let the current widths of boxes A, B, and C be represented by W_A, W_B, and W_C respectively. For the sake of convenience, a co-ordinate system is used which begins at the left edge of the page at zero, and increases to the right of the page. It is also assumed that the letters 'a', 'b', 'c' and 'm' can be understood to mean the location of the corresponding marks within this co-ordinate system.

[0680] The energy of a preferred offset rule is half of the square of the difference between the preferred offset and the actual offset. The objective function for this layout, which is the total energy, is the sum of the energies of all the preferred offset rules. So the objective function is:

$$\begin{aligned}
E(A, B, C) &= \frac{1}{2}(W_A - P_A)^2 + \frac{1}{2}(W_B - P_B)^2 + \frac{1}{2}(W_C - P_C)^2 \\
&= \frac{1}{2}(W_A - 22)^2 + \frac{1}{2}(W_B - 16)^2 + \frac{1}{2}(W_C - 13)^2 \\
&= \frac{1}{2}[(W_A - 22)^2 + (W_B - 16)^2 + (W_C - 13)^2] \\
&= \frac{1}{2}[((m - a) - 22)^2 + ((m - b - 1) - 16)^2 + \\
&\quad ((c - m - 2) - 13)^2] \\
&= \frac{1}{2}[(m - a - 22)^2 + (m - b - 17)^2 + (c - m - 15)^2].
\end{aligned}$$

[0681] Note that to find the width of each box, that box's left-most mark's position is subtracted from its right-most mark's position to obtain a non-negative number. Hence, W_B is (m−b−1) since there is a gap of 1 unit between 'm' and the right edge of box B. Also, W_C is (c−m−2) since 'c' is right of 'm' and there is a distance of 2 units between the left edge of box C and the mark 'm'.

[0682] To minimize the objective function, it is noted that 'm' is the only mark which may move (actually, 'm' and the two marks nearest it may move and any of them may be treated as a controlling variable in the equations, so for simplicity the one named 'm' is used). It suffices in this case to simply find the partial derivative of the energy function with respect to the variable m, and solve for that derivative being zero:

$$E(A, B, C) = \tfrac{1}{2}[(m-a-22)^2+(m-b-17)^2+(c-m-15)^2]$$

$$\delta E/\delta m = (m-a-22)+(m-b-17)+(m-c+15).$$

[0683] Note the reversed sign of the third term (m−c+15) since the derivative is with respect to m, which was negative in that term.

$$\begin{aligned}
\delta E/\delta m &= m - a - 22 + m - b - 17 + m - c + 15 \\
&= 3m - a - b - c - 22 - 17 + 15 \\
&= 3m - a - b - c - 24.
\end{aligned}$$

[0684] It is now possible to find the minimum energy by solving for this value being zero. It is known that a, b, and c have values of 1, 7 and 49 respectively.

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$$0 = 3m - 1 - 7 - 49 - 24$$

$$3m \doteq 1 + 7 + 49 + 24$$

$$= 81$$

$$m = 27.$$

[0685] Since there is only one variable, this ends the procedure. Hence, the lowest energy of the given configuration is when mark 'm' is 27 units right of the left edge of the page.

[0686] 18.3.2 Simple Two-Dimensional Layout Example

[0687] **FIG. 40A** shows another example of usage of the layout mechanism. In this case the example involves tensions in two-dimensions since there are both horizontal and vertical marks which may move.

[0688] There are three boxes **4001** labelled A, B, and C shown within a rectangular page of a known fixed size bounded by marks **4002**. Fixed-offset rules **4003**, **4004**, **4005**, and **4006** determine the location of three edges of each of A and C. The lower horizontal edge of A may move, but is connected via a fixed-offset rule to the upper edge of B (named 'm'), and so those two marks may only be moved together and by the same distance. Similarly, the right edge of B (named 'n') and the left edge of C may be moved but only together by the same distance, since there is a fixed-offset rule between them.

[0689] Since both the width and height of box B may vary, a shape rule has been applied to box B. The rule chosen is an aspect ratio rule which specifies that the ratio of box B's height to its width should be as close to 0.5 as possible (this is indicated by the arrow labelled R_B=0.5 in **FIG. 40A**). Box A has a preferred height of 22 units and box C has a preferred width of 36 units. Since neither of boxes A and C is free to vary in two-dimensions (due to rules **4005**, **4006**), neither has a shape rule.

[0690] The rules in detail are:

[0691] The width of the page is fixed at 50 units.

[0692] The height of the page is fixed at 36 units.

[0693] P_A, the preferred height of container A, is 22 units.

[0694] R_B, the preferred ratio of height to width of container B, is 0.5.

[0695] P_C, the preferred width of container C, is 36 units.

[0696] The upper edge of box A (named 'a') is 2 units from the page's top.

[0697] The left edge of box A is 1 unit right of the page's left edge.

[0698] The right edge of box A is 18 units right of its left edge.

[0699] The upper edge of box B (named 'm') may move.

[0700] The lower edge of box A is 2 units above 'm'.

[0701] The left edge of box B (named 'b') is 1 unit right the page's left edge.

[0702] The lower edge of box B (named 'd') is 3 units above the page's lower edge.

[0703] The right edge of box B (named 'n') may move.

[0704] The left edge of box C is 2 units right of 'n'.

[0705] The lower edge of box C is 3 units above the page's lower edge.

[0706] The right edge of box C (named 'c') is 2 units left of the page's right edge.

[0707] The upper edge of box C is 16 units above its lower edge.

[0708] Let H_A, W_A, H_B, W_B and H_C, W_C be the height and width of box A, the height and width of box B, and the height and width of box C respectively.

[0709] Let P_{HB} and P_{WB} be the preferred height and width of box B, respectively. The preferred heights and widths of box B are not fixed inputs to the layout algorithm; instead they are calculated at certain stages by use of the shape rule for box B, which is an aspect ratio rule relating its width and height. These values are calculated as weighted averages of the height and width of box B:

$$P_{WB}=(W_B+H_B)/(1+R_B)=\tfrac{2}{3}(W_B+H_B)$$

$$P_{HB}=R_B(W_B+H_B)/(1+R_B)=\tfrac{1}{3}(W_B+H_B).$$

[0710] An objective function representing the energy of this arrangement may be obtained as half the sum of the squares of the tensions in both the horizontal and vertical directions:

$$\begin{aligned} E(A, B, C) &= \frac{1}{2}(H_A - P_A)^2 + \frac{1}{2}(H_B - P_{HB})^2 + \\ &\quad \frac{1}{2}(W_B - P_{WB})^2 + \frac{1}{2}(W_C - P_C)^2 \\ &= \frac{1}{2}[(H_A - P_A)^2 + (H_B - P_{HB})^2 + \\ &\quad (W_B - P_{WB})^2 + (W_C - P_C)^2] \\ &= \frac{1}{2}[(m - 2 - a - P_A)^2 + (d - m - P_{HB})^2 + \\ &\quad (n - b - P_{WB})^2 + (c - n - 2 - P_C)^2]. \end{aligned}$$

[0711] To reduce this energy (without actually needing to calculate the energy), it suffices to reduce the partial differentials of the objective function in both horizontal and vertical dimensions, in turn, until the sum of the absolute values of the tensions in both dimensions cannot be reduced further. This produces an arrangement with the lowest tension. The absolute values of the tensions are used so that negative and positive tensions are treated identically in the stopping condition. The partial differentials are:

$$\delta E/\delta m=m-2-a-P_A+m-d+P_{HB}=2m-59+P_{HB}$$

$$\delta E/\delta n=n-c+2+P_C+n-b-P_{WB}=2n-11-P_{WB}$$

[0712] To minimize these partial differentials by setting them each to zero, the following relations are obtained:

$$m=\tfrac{1}{2}(2+a+P_A+d-P_{HB})=\tfrac{1}{2}(59-P_{HB})$$

$$n=\tfrac{1}{2}(c-2-P_C+b+P_{WB})=\tfrac{1}{2}(11+P_{WB}).$$

[0713] For the purposes of this example, let the initial width and height of box B be 15 and 10 units respectively, so m=d−10=33−10=23 and n=b+15=16.

[0714] $W_B=15$

[0715] $H_B=10$

[0716] m=23

[0717] n=16.

[0718] The preferred width and height of the box B may be calculated:

$$\begin{aligned} P_{WB} &= \frac{2}{3}(W_B+H_B) \\ &= \frac{2}{3}(15+10) \\ &= 50/3 \\ &= 16\frac{2}{3} \\ &= 16 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

$$\begin{aligned} P_{HB} &= \frac{1}{3}(W_B+H_B) \\ &= \frac{1}{3}(15+10) \\ &= 25/3 \\ &= 8\frac{1}{3} \\ &= 8 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

[0719] The sum of the absolute values of the horizontal and vertical tensions is calculated so that the layout mechanism can determine when to finish. In this case, the horizontal tension T_X is the sum of the differences between the current widths of boxes B and C and their preferred widths. Similarly, the vertical tension T_Y is the sum of the differences between the current heights of boxes A and B and their preferred heights:

$$\begin{aligned} T_X &= (W_C-P_C)+(W_B-P_{WB}) \\ &= (c-n-2-36)+(n-b-P_{WB}) \\ &= c-38-b-P_{WB} \quad \text{when } n \text{ is eliminated} \\ &= 48-38-1-P_{WB} \\ &= 9-P_{WB} \\ &= 9-16 \\ &= -7. \end{aligned}$$

$$\begin{aligned} T_Y &= (H_B-P_{HB})+(H_A-P_A) \\ &= (d-m-P_{HB})+(m-2-a-22) \\ &= d-P_{HB}-2-a-22, \quad \text{when } m \text{ is eliminated} \end{aligned}$$

-continued

$$\begin{aligned} &= 33-P_{HB}-2-2-22 \\ &= 7-P_{HB} \\ &= 7-8 \\ &= -1. \end{aligned}$$

[0720] The fact the tensions are negative indicates that marks may need to move left or upwards to reduce these tensions.

[0721] The total tension is the sum of the absolute values of the vertical and horizontal tensions:

$$\begin{aligned} T_{TOTAL} &= |T_X|+|T_Y| \\ &= |-7|+|-1| \\ &= 7+1 \\ &= 8. \end{aligned}$$

[0722] The layout mechanism proceeds to reduce tensions in the horizontal and vertical dimensions in turn, until this total tension can no longer be reduced.

[0723] First, vertical marks are moved in a horizontal direction. The preferred width of B was earlier calculated as:

$$\begin{aligned} P_{WB} &= \frac{2}{3}(W_B+H_B) \\ &= 16. \end{aligned}$$

[0724] The only vertical marks which may move are 'n', and the mark connected to it by a fixed-offset rule (2 units to its right). Both marks are moved in such a way as to try to minimize the horizontal tension. It suffices to determine the location to which 'n' should be moved, since the other mark's location may be deduced from that as (n+2). The location of 'n' is calculated to reduce the partial derivative of the objective function with respect to n, as determined earlier by the relation:

$$\begin{aligned} n &= \frac{1}{2}(11+P_{WB}) \\ &= \frac{1}{2}(11+16) \\ &= 13\frac{1}{2} \\ &= 13 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

[0725] The mark 'n' is moved to location 13 to reduce the horizontal tension, which also changes the width of box B to 12:

[0726] $W_B=12$

[0727] $H_B=10$

[0728] m=23

[0729] n=13.

[0730] The preferred width and height of box B have changed due to the shape rule:

$$\begin{aligned} P_{WB} &= \frac{2}{3}(W_B + H_B) \\ &= \frac{2}{3}(12+10) \\ &= 44/3 \\ &= 14\frac{2}{3} \\ &= 14 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

$$\begin{aligned} P_{HB} &= \frac{1}{3}(W_B + H_B) \\ &= \frac{1}{3}(12+10) \\ &= 7\frac{1}{3} \\ &= 7 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

[0731] The total tension must now be recalculated to see if it has reduced, and if it has not, the layout procedure will stop. The new tensions are:

$$\begin{aligned} T_X &= 9 - P_{WB} \\ &= 9 - 14 \\ &= -5. \end{aligned}$$

$$\begin{aligned} T_Y &= 7 - P_{HB} \\ &= 7 - 7 \\ &= 0. \end{aligned}$$

$$\begin{aligned} T_{TOTAL} &= |T_X| + |T_Y| \\ &= |-5| + |0| \\ &= 5. \end{aligned}$$

[0732] Since the total tension has reduced from 8 to 5, the procedure will continue.

[0733] Now, horizontal marks are moved in a vertical direction. In this case only 'm' and the mark connected to it may move. It suffices to calculate the location to which 'm' should be moved, since the connected mark will move to (m−2). The partial derivative of the objective function is minimized with respect to m, as determined earlier by the relation:

$$\begin{aligned} m &= \frac{1}{2}(59 - P_{HB}) \\ &= \frac{1}{2}(59 - 7) \\ &= 26. \end{aligned}$$

[0734] The mark 'm' is moved to location 26 to reduce the vertical tension, and the mark connected to it by a fixed-offset rule moves to location 24.

[0735] W_B=12

[0736] H_B=7

[0737] m=26

[0738] n=13

[0739] The preferred width and height of box B and the total tension are now recalculated:

$$\begin{aligned} P_{WB} &= \frac{2}{3}(W_B + H_B) \\ &= \frac{2}{3}(12+7) \\ &= 38/3 \\ &= 12\frac{2}{3} \\ &= 12 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

$$\begin{aligned} P_{HB} &= \frac{1}{3}(W_B + H_B) \\ &= \frac{1}{3}(12+7) \\ &= 6\frac{1}{3} \\ &= 6 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

$$\begin{aligned} T_X &= 9 - P_{WB} \\ &= 9 - 12 \\ &= -3. \end{aligned}$$

$$\begin{aligned} T_Y &= 7 - P_{HB} \\ &= 7 - 6 \\ &= 1. \end{aligned}$$

$$\begin{aligned} T_{TOTAL} &= |T_X| + |T_Y| \\ &= |-3| + |1| \\ &= 4. \end{aligned}$$

[0740] Since the total tension has reduced from 5 to 4, the procedure will continue. Vertical marks are again moved in a horizontal direction to try to reduce the tension.

$$\begin{aligned} n &= \frac{1}{2}(11 + P_{WB}) \\ &= \frac{1}{2}(11 + 12) \\ &= 11\frac{1}{2} \\ &= 11 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

[0741] Mark 'n' is moved to location 11. The width of box B becomes 10 units.

[0742] W_B=10

[0743] H_B=7

[0744] m=26

[0745] n=11

[0746] The preferred width and height of box B and the total tension are recalculated:

$$\begin{aligned} P_{WB} &= \frac{2}{3}(W_B + H_B) \\ &= \frac{2}{3}(10+7) \\ &= 34/3 \\ &= 11\frac{1}{3} \\ &= 11 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

$$\begin{aligned} P_{HB} &= \frac{1}{3}(W_B + H_B) \\ &= \frac{1}{3}(10+7) \\ &= 5\frac{2}{3} \\ &= 5 \text{ when reduced to the nearest whole unit.} \end{aligned}$$

$$\begin{aligned} T_X &= 9 - P_{WB} \\ &= 9 - 11 \\ &= -2. \end{aligned}$$

$$\begin{aligned} T_Y &= 7 - P_{HB} \\ &= 7 - 5 \\ &= 2. \end{aligned}$$

$$\begin{aligned} T_{TOTAL} &= |T_X| + |T_Y| \\ &= |-2| + |2| \\ &= 4. \end{aligned}$$

[0747] Since the total tension has not reduced below 4, the procedure may stop here. Alternatively, the horizontal marks might also be moved before the procedure stops.

[0748] The final result of this example may look like **FIG. 40B**. Note that box A and C may overlap in this case. This may be the desired effect. If not, to prevent that occurring it may be necessary to add other constraints. For example, a minimum offset rule could be added to force the left edge of box C to remain right of the right edge of box A.

[0749] This example has shown only one shape rule and two preferred-offset rules, but a real application might employ shape rules for each of the boxes. The shape rules may also differ depending on the contents to be displayed within the boxes. For example, both aspect ratio rules and text shape rules may be used. Each would calculate the ideal shape of a box in its own fashion.

[0750] 18.4 Graph Based Algorithm with Fixed Centers

[0751] In the layout engine **105**, use of fixed center rules is allowed, so the layout calculation needs to be modified to correctly handle fixed center rules. A modification to the layout calculation of step **2901** (**FIG. 29**) is shown in **FIG. 30B** as step **2901**-B and is similar to the modification made to support fixed center rules in the push operation. **FIG. 30B** is almost the same as **FIG. 30A**, but shows how fixed centers may be taken into account when calculating the layout. Steps **3001**, **3003**, **3005**, **3009**, **3013**, **3015**, **3019**, **3023** and **3025** are common to **FIGS. 30A and 30B**.

[0752] In **FIG. 30B**, steps **3005** and **3015** must include opposing marks when calculating pushed marks. Instead of calculating a single set of marks to move in one direction, two sets of marks are calculated; one set to be moved to the right and the other set to be moved to the left. This is the same as for the push operation. In **FIG. 30B**, step **3008** replaces step **3007**, where the maximum distance to move is calculated independently for the two sets of marks (ignoring fixed center rules) and then the minimum (in magnitude) of the two values is the maximum distance that the marks can be moved. Steps **3011** is replaced by step **3012**, and step **3021** is replaced by step **3022**, the difference being that both sets of marks are moved. In step **3012**, the set containing the mark chosen in step **3003** is moved to the right and the set containing marks that oppose marks in the first set is moved to the left. In step **3022**, the set containing the mark chosen in step **3003** is moved to the left and the set containing marks that oppose marks in the first set are moved to the right. The same considerations apply as for modifying the push operation to include fixed centers. In this regard, if any two opposing marks are in the same set, then the origin mark should be added to both sets. Logically, all pairs of opposing marks with the same orientation should be included in both sets if the origin mark is included because moving the origin requires that all fixed marks should be moved and hence all boxes with fixed centers must also be moved. Of course, it is unnecessary to actually create sets containing the origin mark and all pairs of opposing marks because they should not be moved anyway. Step **3008** will set the maximum distance to zero if an origin mark is included in either set, so steps **3009**, **3012** and **3013** do nothing and could be skipped. Step **3018** replaces step **3017**, and, like step **3008**, the maximum distance is calculated for both the set containing the mark chosen in step **3003**, but also for all marks that oppose the marks in the set containing the chosen mark. Step **3018** similarly should set the maximum distance to zero if an origin mark is included in either of the two sets.

[0753] 19. Printing Documents

[0754] **FIG. 36** shows a method **3600** steps involved in generating and printing documents from a document template. The method **3600** starts at step **3601** where the application **121** connects to a database and sets a database cursor to the beginning of a table comprising the necessary source data. The user may specify which database to connect to via a dialog as shown in **FIG. 14**. Following step **3601**, at step **3603**, the next record is fetched from the database table and the cursor is updated to point to the next record. Since each document in the document set corresponds to one record, a new document is started, and the page counter is reset to the start of the document template. Step **3605** follows where application **121** commences a new page for the document being produced and a layout for that page is sourced and applied to the page. At step **3607**, the data in the current record is used to calculate the ideal sizes for each container in the layout on the current page. The ideal sizes calculated in step **3607** are then used to adjust the layout rules at step **3609**. Such an operation may comprise changing the values of the preferred offset rules and updating aspect rules based on the ideal sizes calculated in step **3607**. Also, for variable text containers where neither the width nor the height of the text is fixed, the height and width are determined in conjunction with a text rule that depends on text from a field in the database record fetched in step **3603**. Such text rules are also updated in step **3609**. After step **3609**, the layout for the current page is calculated at step **3611**. After the layout has been calculated, the page is rendered and printed at step **3613**. After the page has been

printed, a test is performed at step **3615** to determine whether all pages for the current document have been printed. If not, the method **3600** returns to step **3605** to start the calculations for the next page. If all pages from the document template have been printed for the current document, the method **3600** continues to step **3617**, where another test is performed to determine if the current record is the last record in the database table. If all records in the table have been processed, the method **3600** is complete, otherwise the procedure returns to step **3603**, where the next record in the table is fetched so that the next document can be printed.

[**0755**] 20. Pre-Calculating Possible Text Shapes

[**0756**] One way increase the speed of a layout mechanism, such as the graph-based layout methods described in section 18, is to pre-calculate all shapes of any text which, may be involved in the layout. By calculating the shapes before performing the layout calculations, the layout mechanism may proceed faster because the calculation of text shapes has already been performed and the results stored for rapid later retrieval. A method of calculating the possible shapes of some text is illustrated by examples in **FIGS. 41A-41K**.

[**0757**] The method works in the following way:

[**0758**] 1. Lay the words of the text horizontally end to end with appropriate spacing between the words as required, as in **FIG. 41A** (each word **4102** is shown within a bounding box **4103**). The width and height of this total configuration of words may then be determined as the smallest box **4101** which encloses them. The size of the bounding box **4103** is stored in a memory data structure. Words may be measured using distinct fonts as necessary. Note that a small gap is illustrated between the bounding box **4103** and the word boxes **4102** for the sake of clarity, but this gap would not exist in an actual implementation.

[**0759**] 2. The width of the bounding box is obtained and then reduced by one unit of the co-ordinate system being used. The text is then laid out again using the new width as a width constraint. Text will flow to subsequent lines as required by this width constraint and the rules of text flow of the text's language. There is no height constraint, so as many lines as required may be used. A new bounding box is determined from the result, as in **FIG. 41B**, and this new bounding box is also kept in the memory data structure. The spaces **4105** between words follow the natural spacing rules of the text's language. In English, for example, spaces at the ends of lines will not be counted within the calculation of the bounding box. For some languages the definition of what constitutes a word or an inter-word space may vary from the example given.

[**0760**] 3. Step **2** is repeated until the text cannot be laid out in any less wide a bounding box. **FIGS. 41C** to **41**K exemplify this process. Note that each word, such as the word 'Brevity' in the example, may have optional hyphenation break-points **4104** within it, which allows that word to be broken, as shown in **FIGS. 41***h* to **41***k*. When this occurs in English the rule is to add a hyphen **4106**. The size and placement of such dynamically inserted punctuation marks would typically be included in the calculation of any bounding box, although this would depend on the rules of the text's language.

[**0761**] 4. The calculated shapes of the text are the stored bounding boxes. These shapes may be used in a layout mechanism when it is necessary to know how large a piece of text may be, given a constraint on width or height or both. These shapes may also be used to know what the next largest or next smallest shape is in a given dimension, so as to quickly decide between several possible layouts of a piece of text.

[**0762**] This described implementation is clearly intended to be used with languages which are written from left to write, using inter-word spaces of a known minimal size. Alternative arrangements may be made for languages which do not follow these rules. For example, some Asian languages write characters from top to bottom in columns and then these columns are written from right to left. For such languages, the laying out process would be modified to swap the role of the vertical and horizontal dimensions, and the size of a space character may be reduced to some smaller value or zero. Thus, characters would be stacked vertically in step 1, and then in step 2 the height would be reduced by 1 unit (which could be the height of a character) and the process repeated to form wider and wider bounding boxes. Similarly, the hyphenation rules of each language will depend on the text's language.

[**0763**] 21. Table Creation Example

[**0764**] **FIGS. 42A-42C** show some methods of constructing tables using a graph-based layout mechanism as described in section 18. A table is defined as a rectangular area which is divided into cells, each cell optionally holding some contents such as text or an image.

[**0765**] **FIG. 42A** shows one method of defining a table. Guides **4203** are used to define column and row positions. Containers **4201** are placed between the guides to act as cells in the table where contents may be placed. Struts **4202** are attached between the guides **4203** and the corresponding adjacent edges of the containers **4201** to define margins between the contents of adjacent cells. Such struts may have any required length, including a length of zero if the cells are intended to be flush against each other.

[**0766**] The guides may be unfixed (they may be floating guides) so that the contents of each cell may push them, thus allowing the row and column sizes to adjust to accommodate different-sized contents. Alternatively, the guides may be fixed to the page to restrict the columns or rows to a certain size or location. Floating guides can also be used to control column and row sizes by placing struts between the guides. This allows the entire table to move on the page (since the guides are not fixed to the page) but the sizes of columns and rows may nevertheless be controlled by this technique.

[**0767**] Note that the outer edges of the containers in this table are fixed to the page. This might not be necessary. An alternative better method might be to also use guides to define the outermost boundary of the table and place struts between those guides and the outer edges of the containers, to allow those edges to move together.

[**0768**] **FIG. 42B** shows an alternative method of defining a table. In this example, guides are not used. Instead, struts

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4205 are attached directly between the edges of adjacent containers **4204**, to specify the margin size of columns and rows. Such margin-specifying struts **4205** are only needed between the top-most and left-most containers. Other containers within the table are linked to these constraints using zero-length struts **4206**.

[**0769**] In the example given in **FIG. 42B**, the bottom edges of the upper row of containers are linked by a zero-height strut **4206** so that their bottom edges are aligned exactly with each other. Similarly the top edges of the lower row of containers are linked by a zero-height strut so that they are aligned. Together, this means only one vertical strut **4205** is needed to define and control the margin size between those two rows. In practice this may be quite useful as it means changes to a table's margins can only involve changing one strut's preferred or actual distance, rather than changing many struts as the example in **FIG. 42A** might require. A similar logic holds for the zero-width struts **4206** shown linking the right edges of the left-most column and also linking the left edges of the right-most column.

[**0770**] As in **FIG. 42A**, the example in **FIG. 42B** also has the outer edges of the table fixed to the page. Instead of fixing the location and size of the table this way, it is possible to use zero-length struts to align all of the outer edges of the containers, just as the inner edges are aligned. This allows the table to be moved wherever needed on a page without needing to change the location of many fixed outer edges one by one. This approach may be made using the layout method described in Section 18.3.

[**0771**] A third alternative may use guides to define the outer edges of a table, and zero-length struts to align the inner edges of the table. There are many other viable combinations of guides and struts which achieve similar results.

[**0772**] Note that some method of aligning the inner edges of a table is needed to form the traditional notion of a table. **FIG. 42C** shows what can happen if neither guides nor struts are used to align inner edges. Containers **4207** are again being used as table cells, and struts **4208** are used to define the distances between adjacent containers. Notice, however, that this example lacks a way to keep diagonally opposite containers from overlapping, because the inner edges of columns and rows are not kept apart.

[**0773**] This might lead to interesting and viable arrangements of containers and contents, and the layout method described in Section 18.3 and later is capable of producing such arrangements (not all prior art examples of layout methods can). For the traditional notion of a table, however, the examples shown in **FIGS. 42A and 42B** are better suited to achieve well-aligned columns and rows.

Industrial Applicability

[**0774**] The arrangements described are applicable to the computer and data processing industries and particularly to situations where large numbers of documents having essentially the same format and layout are to be reproduced with varying data. Examples of this include the generation of correspondence for a large number of persons all of whom have different names and addresses and other personal details. Another example could be for the generation of advertising brochures relating to different holiday destinations each of being characterized by unique content including text and images but by which all brochures are generated according to a common layout indicative of the brand or get-up of the organization conducting the advertising. Many other examples also apply.

[**0775**] The foregoing describes only some embodiments of the present invention, and modifications and/or changes can be made thereto without departing from the scope and spirit of the invention, the embodiments being illustrative and not restrictive.

We claim:

1. A method of proofing a plurality of variable data documents each formed from a common layout in which variable data content is placed into one or more containers having locations and sizes within said layout defined by layout rules, said method comprising the steps of:

(a) assessing a plurality of measures of variation for each said container in each said document;

(b) determining the measure of a standard document generated from said common layout;

(c) comparing the measure of said determined standard document with the measure of said assessed plurality of measures; and

(d) presenting a document having at least one measure for which the compared result is larger among said assessed plurality of measures based on the result of said comparison.

2. A method according to claim 1 wherein step (b) comprises:

(ba) determining an average said measure of variation for each said container over all said documents;

(bb) for each said document:

(bba) calculating a measure of deviation for each said container from said corresponding average measure of variation using said corresponding assessed measure of variation;

(bbb) processing the measures of deviations to obtain a deviation value for said document; and

step (c) comprises comparing the deviation values of said documents to identify at least one group of said documents for presentation for further assessment.

3. A method according to claim 2 wherein said one group comprises documents possessing the largest of said deviation values.

4. A method according to claim 2 wherein said one group comprises documents possessing the smallest of said deviation values.

5. A method according to claim 2 wherein said measure of variation comprises a size of said container.

6. A method according to claim 2 wherein said size is determined as an area of said container by multiplying the corresponding height and width.

7. A method according to claim 2 wherein said size comprises a summation of the corresponding height and width of said container.

8. A method according to claim 2 wherein said measure of variation comprises a measure of edge positions of said container.

9. A method according to claim 5 wherein:

step (a) comprises determining both minimum and maximum container size for each said container in each said document; and

step (bba) comprises calculating a maximum size deviation for each said container from said corresponding average container size using said corresponding minimum and maximum container sizes.

10. A method according to claim 2 wherein step (bbb) comprises statistically summing the squares of the deviations to obtain said deviation measure for said document.

11. A method according to claim 2 wherein step (a) comprises performing layout calculations for each said container without rendering of content within said containers.

12. A method according to claim 2 wherein step (a) comprises computations over all edges of each said container.

13. A method according to claim 2 wherein step (c) comprises the sub-steps of:

(ca) ranking the measures of deviation from smallest to largest; and

(cb) selecting said one group as a determinable number of said documents from one extremity of the ranking.

14. A method according to claim 2 wherein said further assessment comprises manual examination of said group of documents.

15. A method according to claim 13 wherein said one extremity comprises those said documents having the largest of said deviation values, and step (d) comprises printing those one of said documents not being part of said one group.

16. A method according to claim 15 wherein said one group of documents are independently laid out.

17. A method according to claim 2 wherein said method steps are performed upon user instigation upon an established said layout.

18. A method according to claim 1 wherein

step (a) comprises assessing a size for each said container in each said document;

step (b) comprises summing the assessed sizes for each said document to obtain a measure of corresponding document size;

step (c) comprises ranking the measures in size order; and

step (d) presenting for further assessment at least one sub-set of said documents from said ranked measures.

19. A method according to claim 18 wherein said one sub-set is selected from the group consisting of:

(i) a predetermine number of smallest sized documents;

(ii) a predetermined number of largest sized documents; and

(iii) a predetermined number of centrally ranked documents representing an approximate average size of said documents.

20. A method according to claim 18 wherein said method steps are performed upon user instigation upon an established said layout.

21. A method according to claim 1 wherein

step (a) comprises assessing a size for each said container in each said document;

step (b) comprises summing the assessed sizes for each said document to obtain a printed size value for each said document;

step (c) comprises: (ca) subtracting the printed size value from the corresponding document size to determine a white space value for each said document; and

(cb) ranking the white space values in order; and

step (d) comprises presenting for further assessment at least one sub-set of said ranked documents.

22. A method according to claim 21 wherein said method steps are performed upon user instigation upon an established said layout.

23. A method of creating a layout for a variable data document based upon a template, said method comprising the steps of:

(a) establishing the template in a graphical user interface;

(b) setting at least one container in the template to form said layout;

(c) modifying the layout to thereby generate an exemplary document by placing exemplary content into said at least one container, wherein at least one dimension of said least one container and/or a position of said at least one container in said layout are varied based upon at least a property of the placed content; and

(d) displaying said exemplary document in said layout via said graphical user interface.

24. A method according to claim 23 further comprising the step of:

(e) modifying the layout by varying a feature of said at least one container in said layout; and

(f) repeating steps (c) and (d) to display the modified exemplary document.

25. A method according to claim 24 wherein the varying comprises setting a constraint upon at least one feature of said at least one container.

26. A method according to claim 25 wherein said constraint is selected from the group consisting of:

(i) a constraint between said one container and a print margin of a page in which said container is placed;

(ii) a constraint relating to a size of said one container; and

(iii) a constraint relating said feature of said one container with a feature of another said container in said layout.

27. A method according to claim 23 wherein said exemplary content comprises a single record of content selected by a user from a set of records of content from which a corresponding set of variable data documents is to be formed.

28. A computer readable medium having a computer program recorded thereon, said program being adapted to make a computer execute a procedure to proof a plurality of variable data documents each formed from a common layout in which variable data content is placed into one or more containers having locations and sizes within said layout defined by layout rules, said program comprising:

code for assessing a plurality of measures of variation for each said container in each said document;

code for determining the measure of a standard document generated from said common layout

code for comparing the measure of said determined standard document with the measure of said assessed plurality of measures; and

code for presenting a document having at least one measure for which the compared result is larger among said assessed plurality of measures based on the result of said comparison.

29. A computer readable medium having a computer program recorded thereon, said program being adapted to make a computer execute a procedure to create a layout for a variable data document based upon a template, said program comprising:

code for establishing the template in a graphical user interface;

code for setting at least one container in the template to form said layout;

code for modifying the layout to thereby generate an exemplary document by placing exemplary content into said at least one container, wherein at least one dimension of said least one container and/or a position of said at least one container in said layout are varied based upon at least a property of the placed content; and

code for displaying said exemplary document in said layout via said graphical user interface.

30. Computer apparatus for proofing a plurality of variable data documents each formed from a common layout in which variable data content is placed into one or more containers having locations and sizes within said layout defined by layout rules, said apparatus comprising:

means for assessing a plurality of measures of variation for each said container in each said document;

means for determining the measure of a standard document generated from said common layout;

means for comparing the measure of said determined standard document with the measure of said assessed plurality of measures; and

means for presenting a document having at least one measure for which the compared result is larger among said assessed plurality of measures based on the result of said comparison.

31. Computer apparatus for creating a layout for a variable data document based upon a template, said apparatus comprising:

means for establishing the template in a graphical user interface;

means for setting at least one container in the template to form said layout;

means for modifying the layout to thereby generate an exemplary document by placing exemplary content into said at least one container, wherein at least one dimension of said least one container and/or a position of said at least one container in said layout are varied based upon at least a property of the placed content; and

means for displaying said exemplary document in said layout via said graphical user interface.

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