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(54) **VISUALIZING AND AUDITING ELECTIONS AND ELECTION RESULTS**

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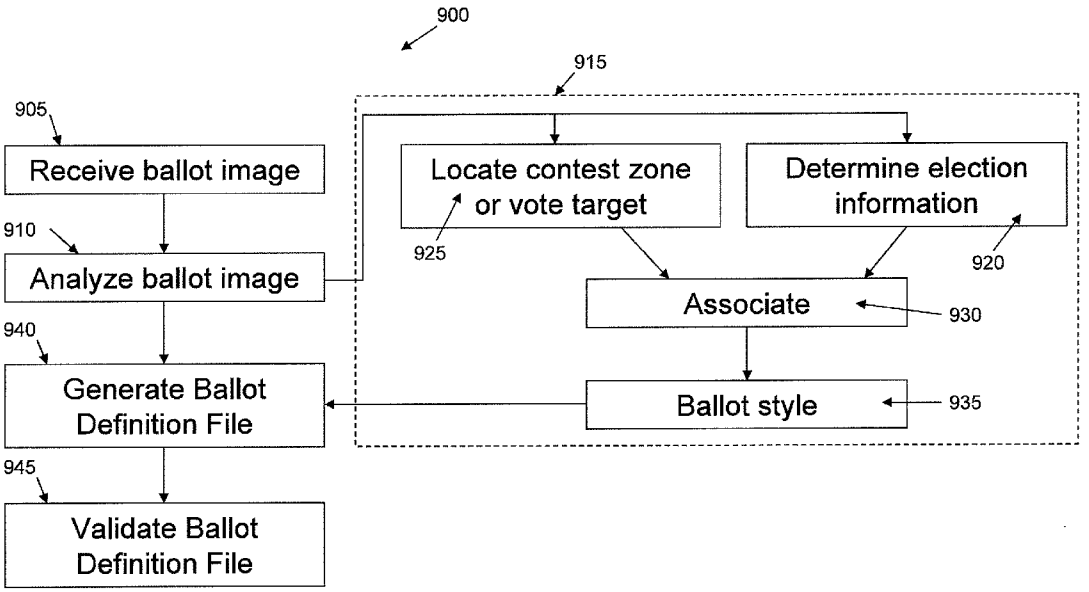
(57) **ABSTRACT**

Described are methods, systems, and computer program products for auditing an election. A computer-readable image of a ballot is received. The image of the ballot is analyzed with a computerized image analysis tool to generate a ballot definition file associated with the ballot. The ballot definition file is validated. Validation involves comparing a predicted election outcome and a simulated election outcome based on tabulation of machine-marked ballots using the ballot definition file. Auditing an election involves comparing a predicted election outcome generated by processing voter-marked ballots with the validated ballot definition file in one vote tabulator and an actual election outcome generated by an election department using its own ballot definition file and vote tabulator to process the voter-marked ballots.



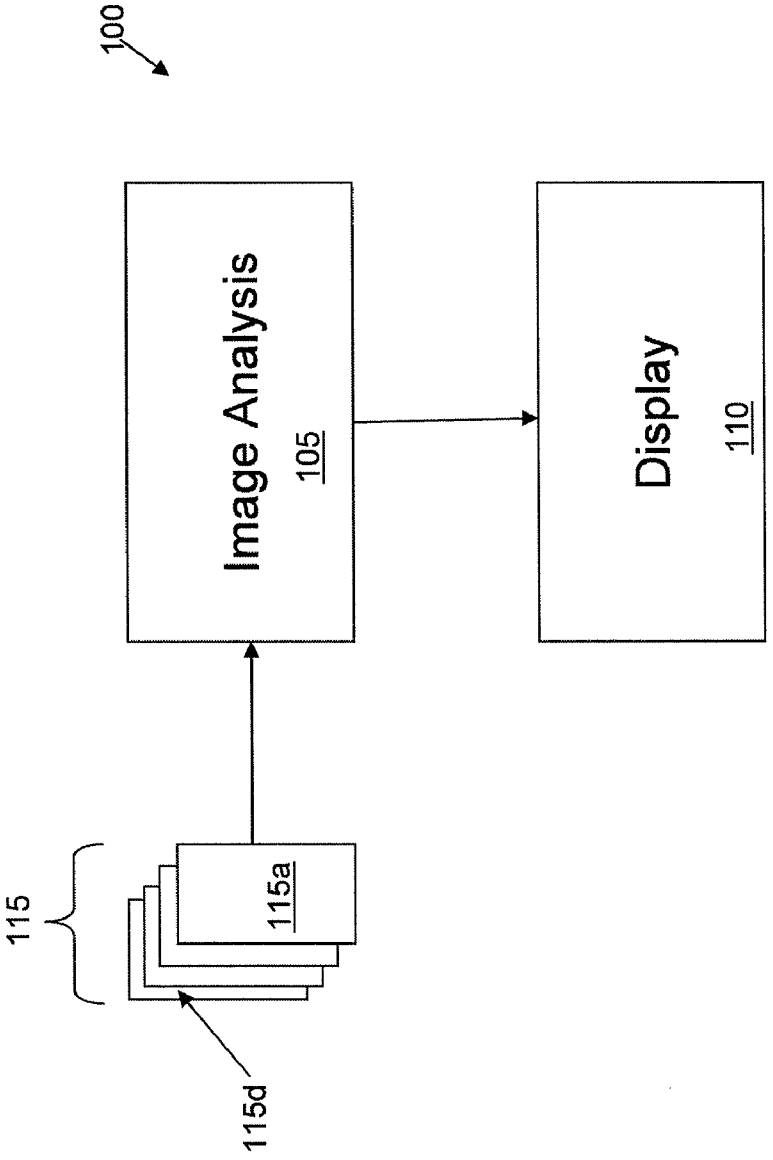


FIG. 1

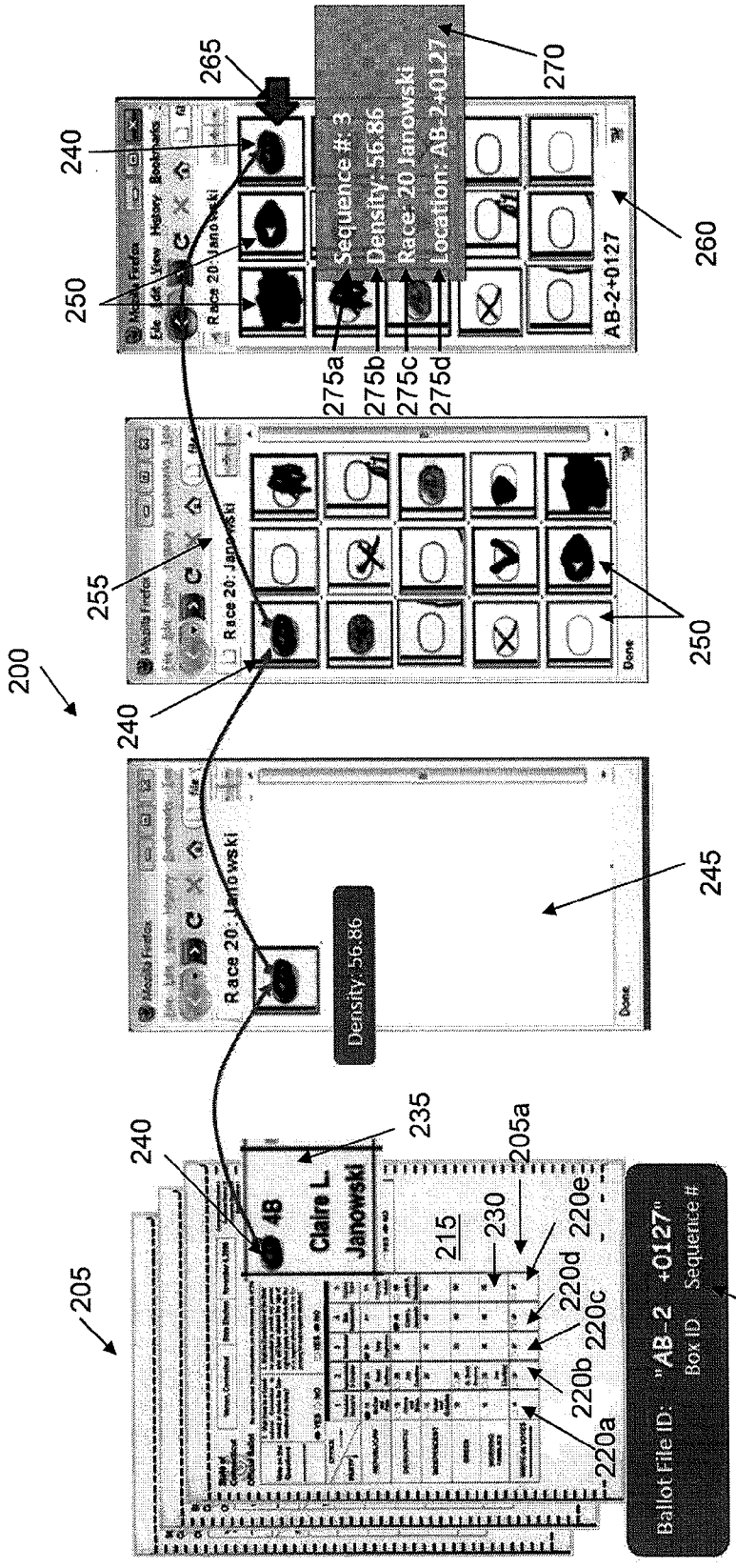

200
205
210
215
220a
220b
220c
220d
220e
225a
225b
230
235
240
245
250
255
260
265
270
275a
275b
275c
275d
Race 20: Janowski
Density: 56.86
Sequence #: 3
Density: 56.86
Race: 20 Janowski
Location: AB-2+0127
AB-2+0127
Claire L
Janowski
Ballot File ID: "AB-2 +0127"
Box ID Sequence #

FIG. 2

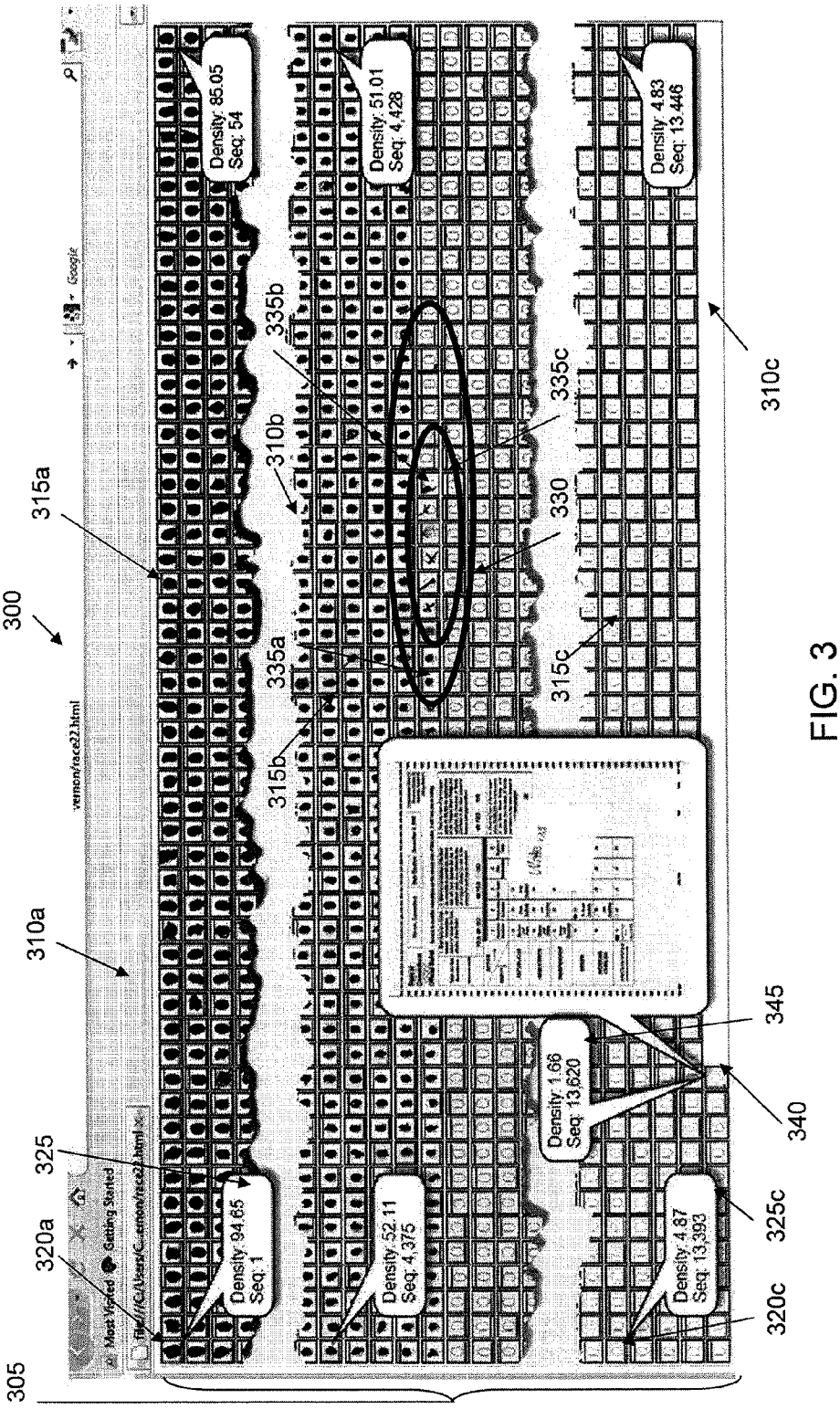

Density: 85.05
Seq: 54
Density: 51.01
Seq: 4,428
Density: 4.83
Seq: 13,446
Density: 94.65
Seq: 1
Density: 52.11
Seq: 4,375
Density: 1.66
Seq: 13,620
Density: 4.87
Seq: 13,393
300
305
310a
310b
310c
315a
315b
315c
320a
320c
325
325c
330
335a
335b
335c
340
345

FIG. 3

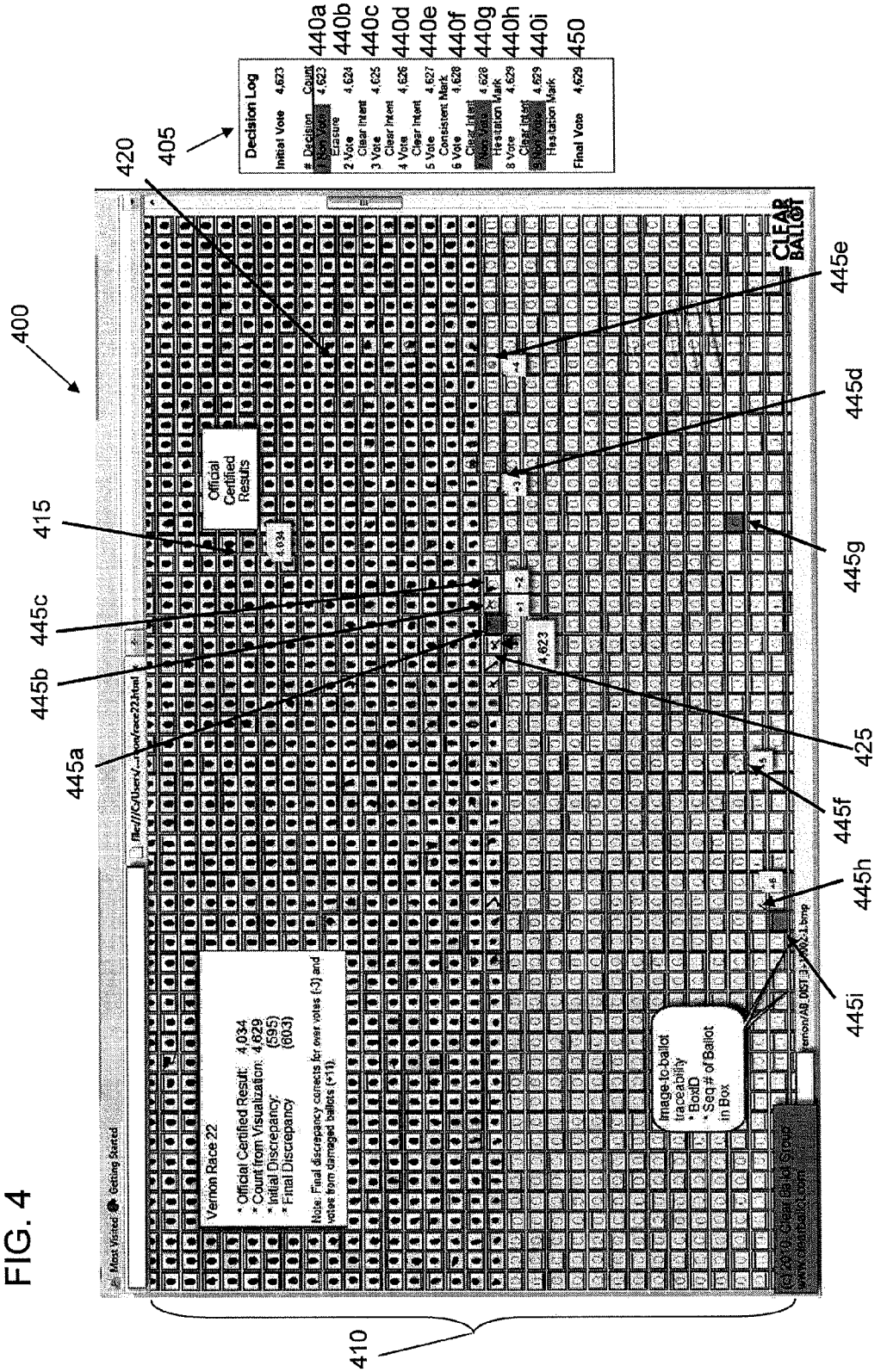

400
405
420
415
410
Decision Log
Initial Vote 4,623
Decision Count
1 Vote 4,623
2 Vote 4,624
3 Vote 4,625
4 Vote 4,626
5 Vote 4,627
6 Vote 4,628
7 Vote 4,628
8 Vote 4,629
9 Vote 4,629
Final Vote 4,629
440a
440b
440c
440d
440e
440f
440g
440h
440i
450
Official Certified Results
Vernon Race 22
* Official Certified Result: 4,034
* Count from Visualization: 4,629
* Initial Discrepancy: (595)
* Final Discrepancy (603)
Note: Final discrepancy corrects for over votes (-3) and votes from damaged ballots (+11).
Image-to-ballot traceability
* BoxID
* Seq # of Ballot in Box
445a
445b
445c
445d
445e
445f
445g
445h
445i
425
CLEAR BALLOT

FIG. 4

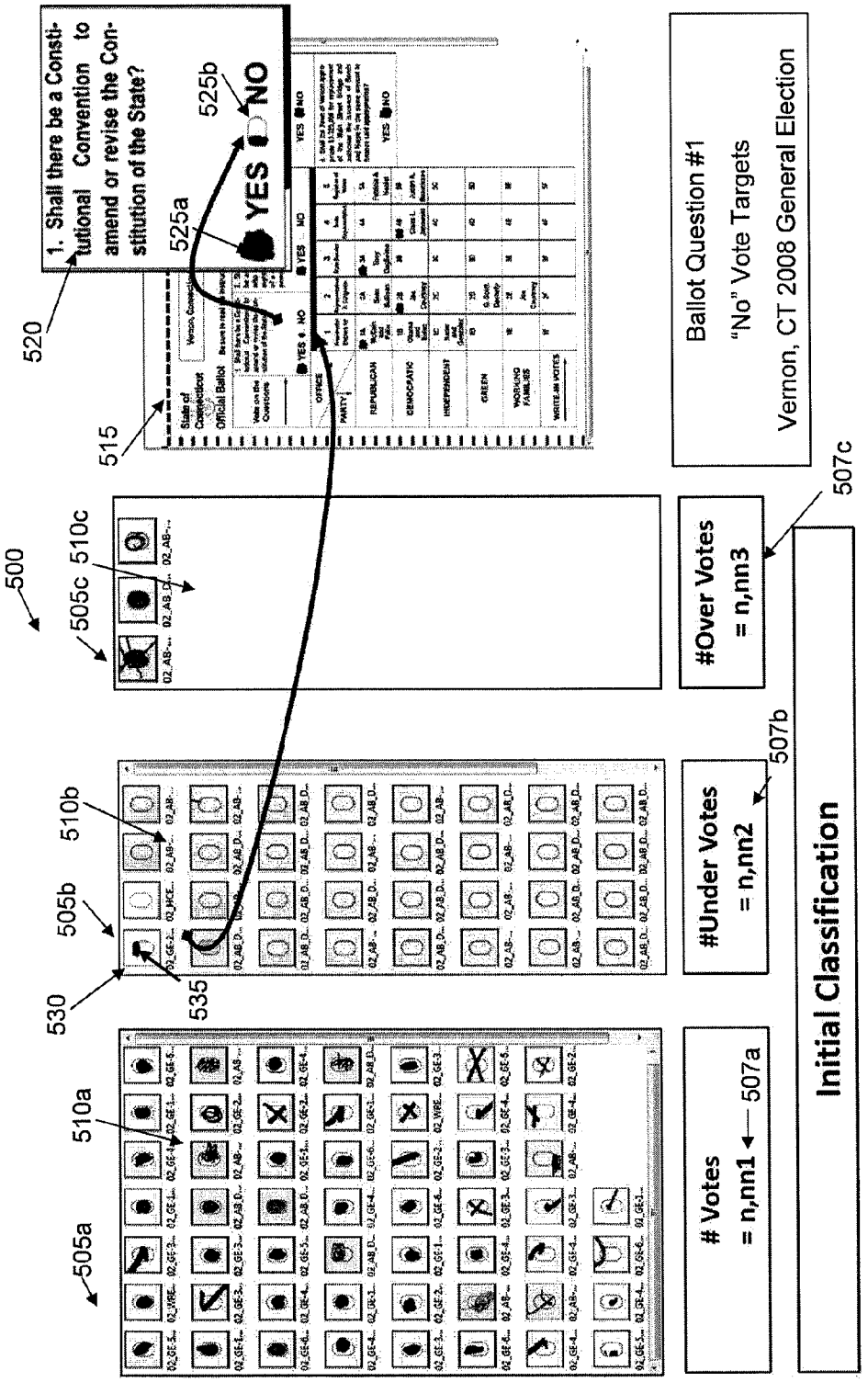

1. Shall there be a Constitutional Convention to amend or revise the Constitution of the State?
YES
NO
520
525a
525b
515
500
505c
510c
505b
510b
505a
510a
530
535
#Over Votes = n,nn3
507c
#Under Votes = n,nn2
507b
Votes = n,nn1
507a
Initial Classification
Ballot Question #1
"No" Vote Targets
Vernon, CT 2008 General Election

FIG. 5

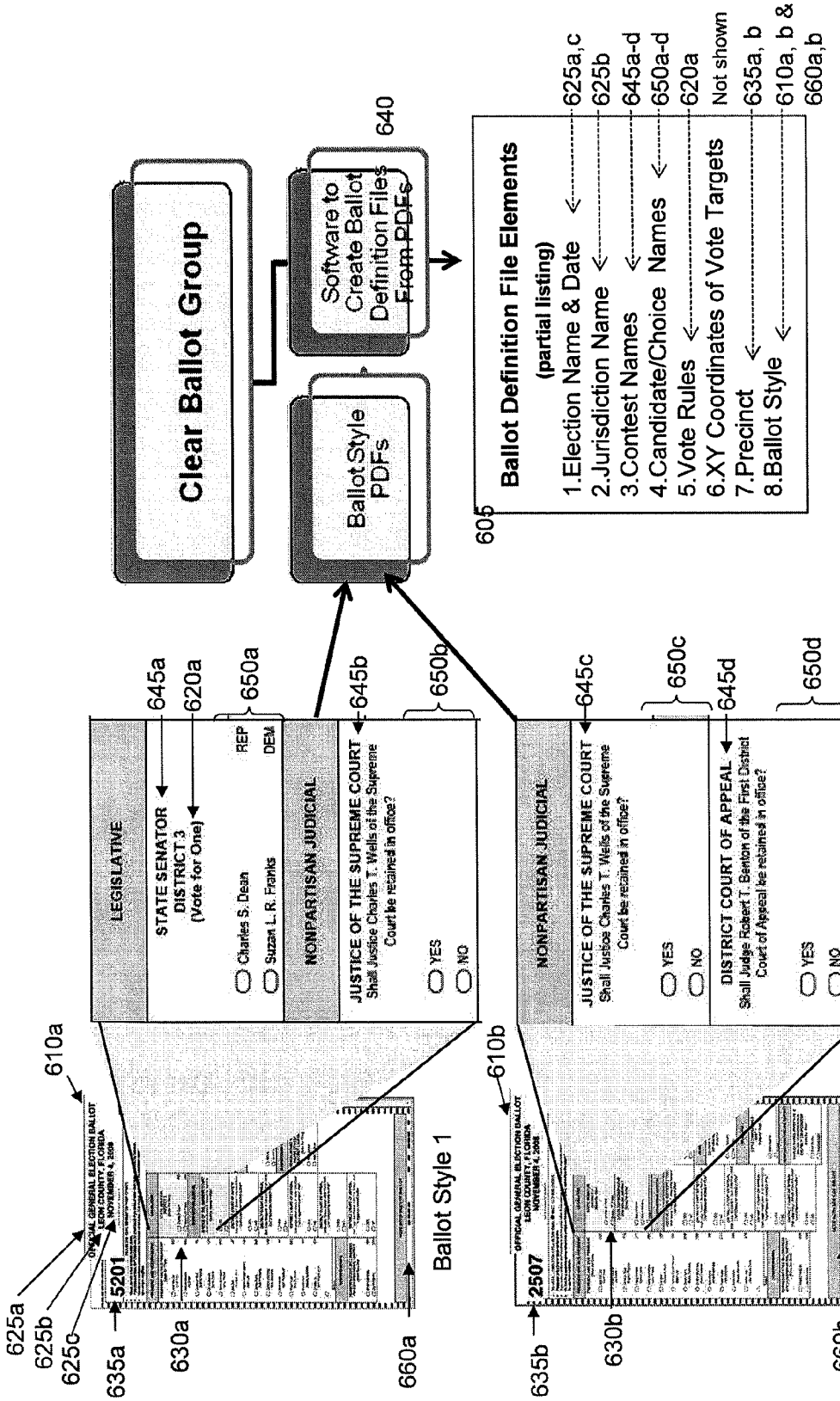

600
Clear Ballot Group
Ballot Style PDFs
Software to Create Ballot Definition Files From PDFs
640
605
Ballot Definition File Elements
(partial listing)
1.Election Name & Date
2.Jurisdiction Name
3.Contest Names
4.Candidate/Choice Names
5.Vote Rules
6.XY Coordinates of Vote Targets
7.Precinct
8.Ballot Style
625a, c
625b
645a-d
650a-d
620a
Not shown
635a, b
610a, b &
660a,b
610a
610b
645a
620a
650a
645b
650b
645c
650c
645d
650d
625a
625b
625c
635a
630a
660a
635b
630b
660b
5201
2507
LEGISLATIVE
STATE SENATOR
DISTRICT 3
(Vote for One)
REP
DEM
Charles S. Dean
Suzan L.R. Franks
NONPARTISAN JUDICIAL
JUSTICE OF THE SUPREME COURT
Shall Justice Charles T. Wells of the Supreme Court be retained in office?
YES
NO
DISTRICT COURT OF APPEAL
Shall Judge Robert T. Benton of the First District Court of Appeal be retained in office?
Ballot Style 1
Ballot Style 2

FIG. 6

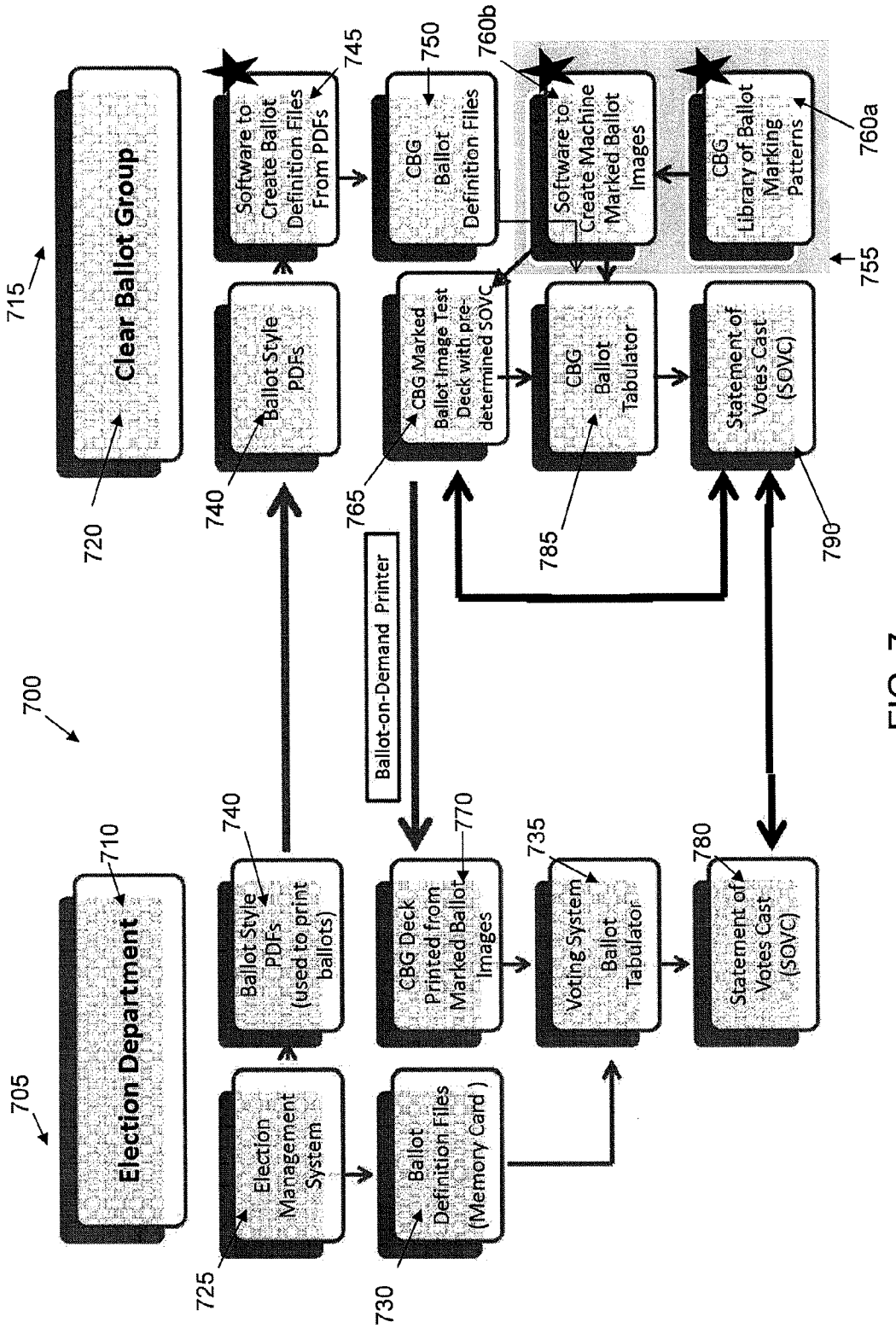

700
705
Election Department
710
Election Management System
725
Ballot Definition Files (Memory Card)
730
Ballot Style PDFs (used to print ballots)
740
CBG Deck Printed from Marked Ballot Images
770
Voting System Ballot Tabulator
735
Statement of Votes Cast (SOVC)
780
Ballot-on-Demand Printer
715
Clear Ballot Group
720
Ballot Style PDFs
740
Software to Create Ballot Definition Files From PDFs
745
CBG Ballot Definition Files
750
CBG Marked Ballot Image Test Deck with pre-determined SOVC
765
CBG Ballot Tabulator
785
Statement of Votes Cast (SOVC)
790
Software to Create Machine Marked Ballot Images
760b
CBG Library of Ballot Marking Patterns
760a
755

FIG. 7

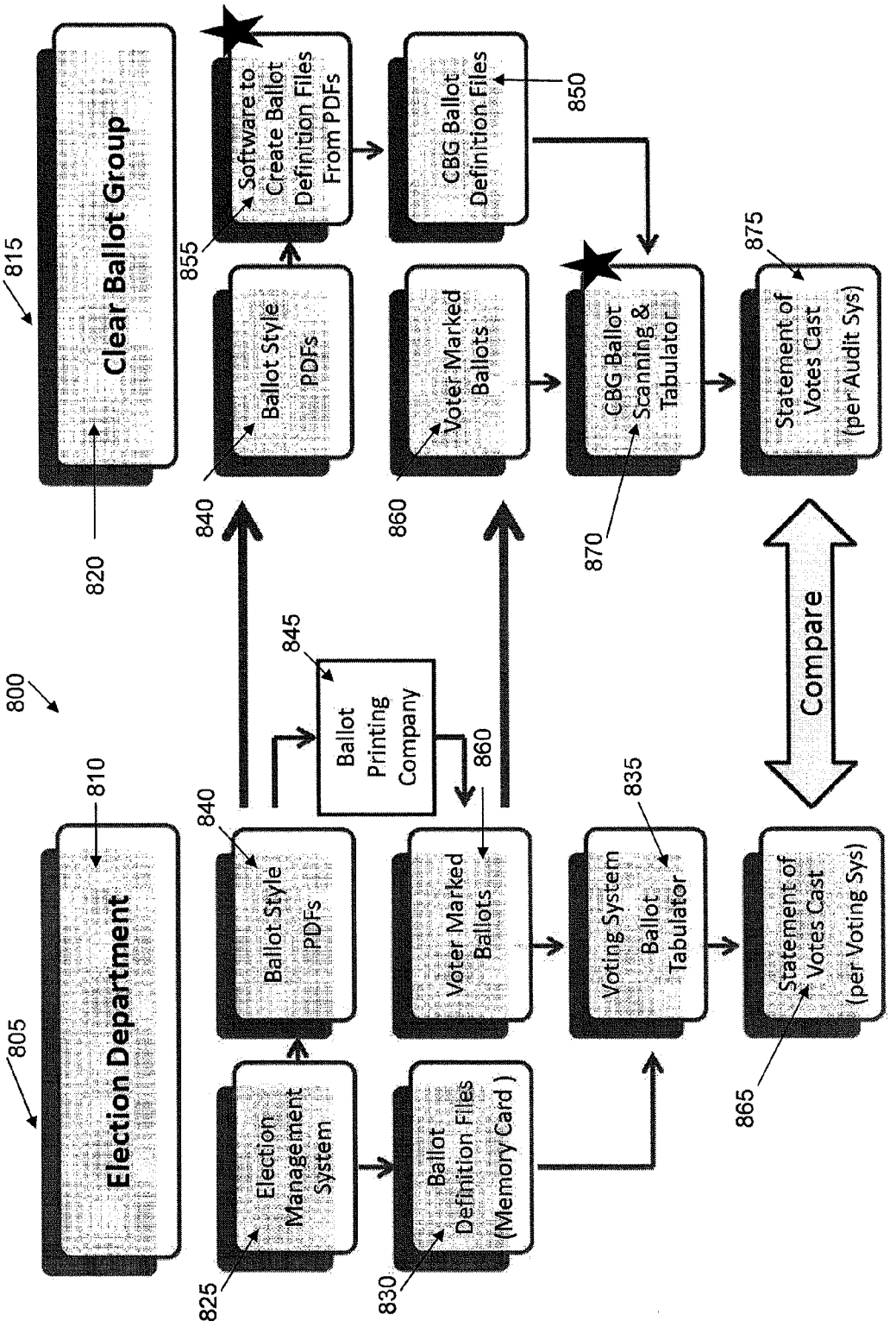

800
805
Election Department
810
825
Election Management System
830
Ballot Definition Files (Memory Card)
840
Ballot Style PDFs
845
Ballot Printing Company
860
Voter Marked Ballots
835
Voting System Ballot Tabulator
865
Statement of Votes Cast (per Voting Sys)
815
Clear Ballot Group
820
855
Software to Create Ballot Definition Files From PDFs
850
CBG Ballot Definition Files
870
CBG Ballot Scanning & Tabulator
875
Statement of Votes Cast (per Audit Sys)
Compare

FIG. 8

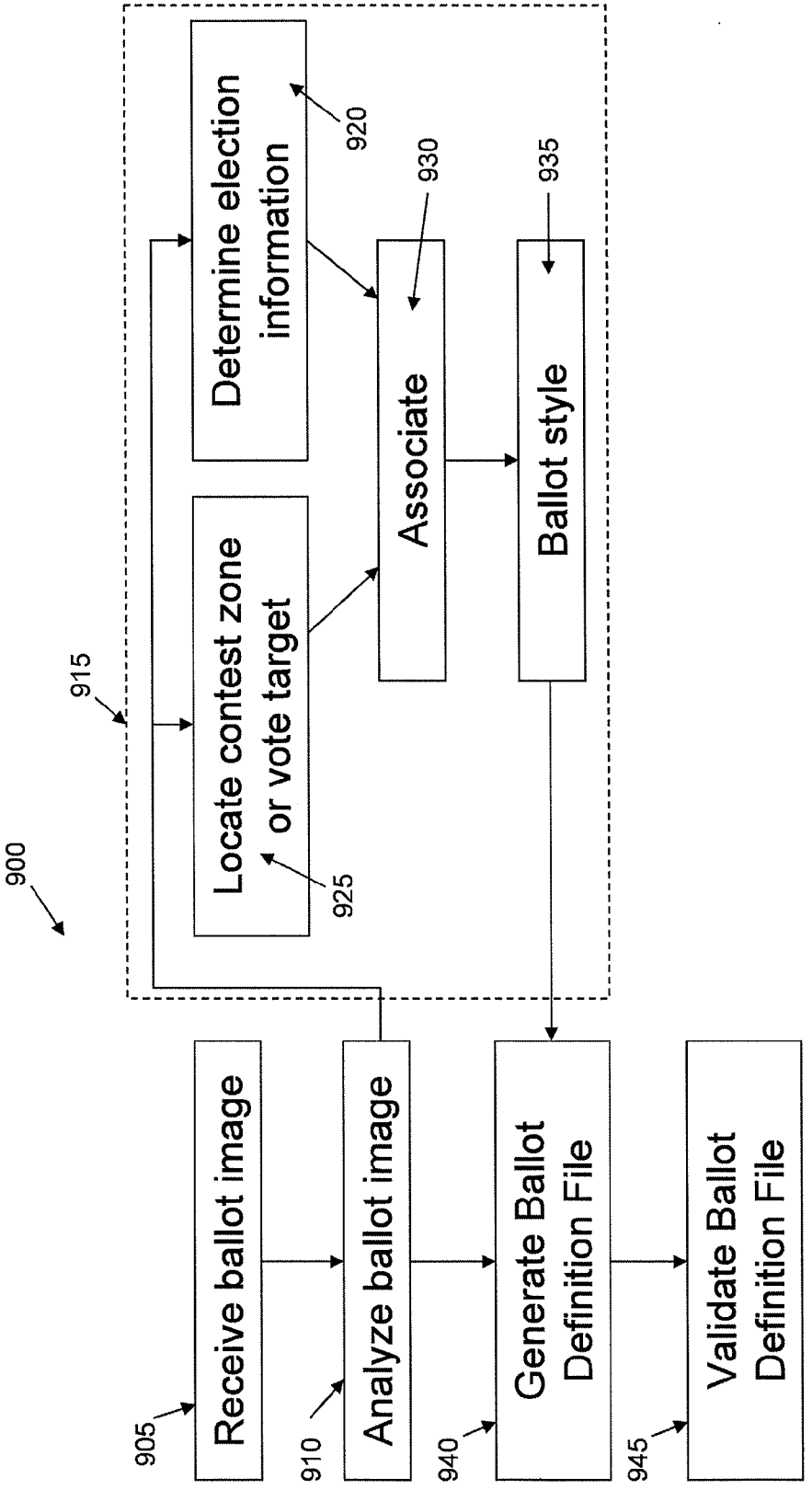

900
915
Determine election information
920
Locate contest zone or vote target
925
Associate
930
Ballot style
935
Receive ballot image
905
Analyze ballot image
910
Generate Ballot Definition File
940
Validate Ballot Definition File
945

FIG. 9

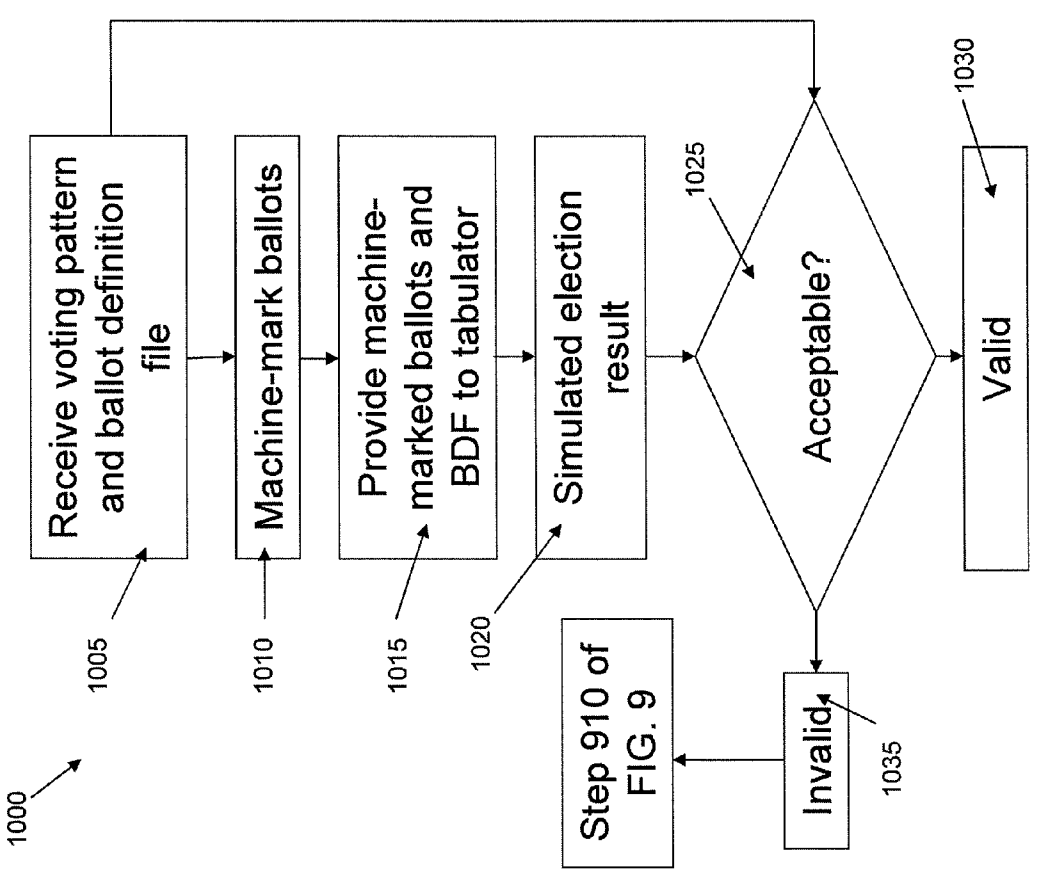

1000
Receive voting pattern and ballot definition file
1005
Machine-mark ballots
1010
Provide machine-marked ballots and BDF to tabulator
1015
Simulated election result
1020
Acceptable?
1025
Valid
1030
Invalid
1035
Step 910 of FIG. 9

FIG. 10

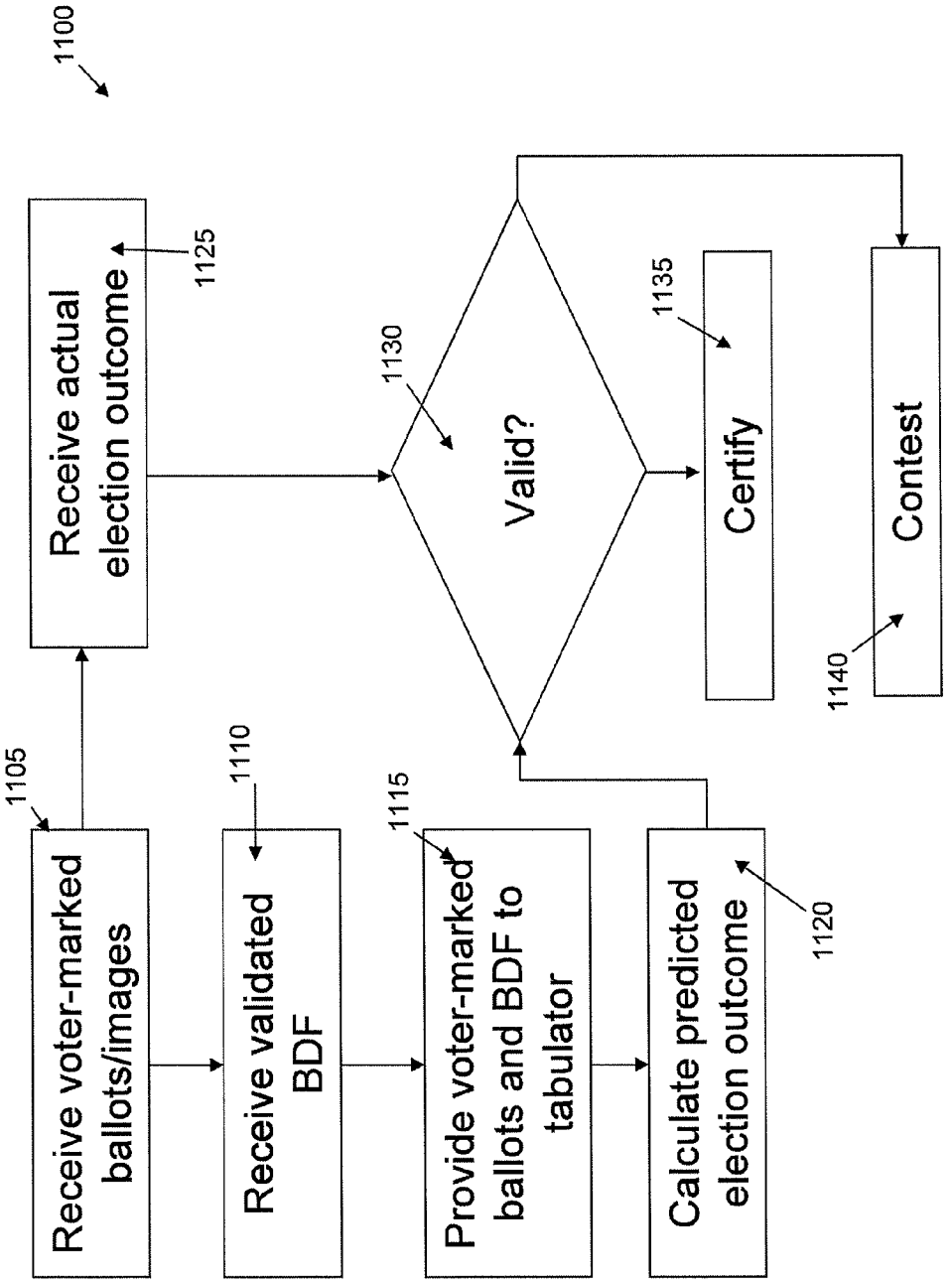

1100
Receive voter-marked ballots/images
1105
Receive validated BDF
1110
Provide voter-marked ballots and BDF to tabulator
1115
Calculate predicted election outcome
1120
Receive actual election outcome
1125
Valid?
1130
Certify
1135
Contest
1140

FIG. 11

VISUALIZING AND AUDITING ELECTIONS AND ELECTION RESULTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The application claims priority to and the benefit of U.S. Patent Application No. 61/428,153 titled "Visualizing and Auditing Elections and Election Results," by Moore et al. filed Dec. 29, 2010, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] The description generally relates to visualizing and auditing elections and election results.

BACKGROUND

[0003] Generally, representative democracies are based on the free election of individuals to representative office and/or electoral questions on laws or regulations (e.g., ballot referenda and the like). Faith in elections is often considered fundamental to the function of free societies. As the size of communities and registered voters has grown, local election departments have transitioned from hand-counted elections to machine-counted elections. In a machine-counted election, vote readers interpret marked ballots (e.g., voter-marked ballots) to determine whether the ballot indicates a voter's intended vote. The vote readers count the number of marked ballots and communicate with a vote tabulator that accumulates the vote totals from the vote readers. The accumulated vote totals are used to determine the election winner(s). Each vote reader and/or vote tabulator is programmed to read and/or analyze ballots to discern voter intent. The programming is generally proprietary to the company making the reader/tabulator and is thus susceptible to fears about errors or hacking resulting in erroneous or fraudulent election results.

[0004] An election department typically certifies an election result based, at least in part, on the accumulated vote totals from the vote tabulator. If an election is contested, a recount (either machine or manual) normally occurs prior to election certification. After certification, a party dissatisfied with an election result is left without recourse. During a recount, ballots are manually examined and evaluated to discern voter intent. Voter intent is evaluated based on markings on the marked ballot, typically in areas on the ballot that are designated for voter intent such as markable ovals. Additionally, voter intent can be discerned based on a particular marking in the context of other markings on the ballot for other elections.

[0005] Typically, an election recount is a laborious, time-intensive, and expensive process. As a prominent example, the recount in the 2000 presidential election proceedings in Florida took approximately thirty-six days. More recently, in the 2008 senatorial recount proceedings in Minnesota took approximately eight months. These delays led to uncertainty and expense while the winner of the election was in question. Another concern is a situation in which an error in vote reading or tabulating is not determined or known, in which case a recount that might otherwise be implemented before certification is not effected, possibly resulting in the person receiving the most actual votes not taking office or a question that garnered enough actual votes to pass not passing (or vice versa).

[0006] Because of the human element in a voter marking a ballot, the vote reader must make certain determinations about whether a marking constitutes a vote (sometimes called an adjudicated vote). The vote reader can also determine whether a marking constitutes a non-vote, an over-vote (i.e., more votes than the election rules permit for that election), and an under-vote (i.e., fewer votes than the election rules permit for that election). The vote reader may miss a marking that constitutes a vote (e.g., referred to as uncaptured voter intent) or a marginal vote (e.g., a marking that, by itself, does not indicate intent but, in the context of the other markings on the ballot can be used to infer intent).

[0007] Additionally, each election department or district is often responsible for administering its own elections, including generation or printing of ballots, counting ballots, and certifying the counted votes. Because many elections are local or district- or precinct-specific, ballots tend to be unique. Differences in ballots and ballot types make universal auditing solutions difficult to implement economically.

SUMMARY

[0008] Therefore, there is a need for tools to assist those auditing elections and doing so in an automatable, repeatable, and verifiable way to engender trust in the election and/or audit results. There is a need for tools to prepare ballots, which constitute a large data set of uniquely-identified data, for analysis and presentation.

[0009] The concepts described herein address the problem by providing tools for quickly and intuitively organizing and reviewing or presenting for review a large amount of data collected from individual ballots that vary precinct-by-precinct or district-by-district. The techniques described here allow for faster, more accurate, and verifiable election recounts and support for the decision to declare an election recount. Additionally, the techniques allow for testing, auditing, and analysis of elections independent of an official election department, thereby facilitating independent review and leading to increased confidence in any particular election and the ballot-counting process in general.

[0010] In particular, described here are methods, systems, and computer program products for visualizing an election, for auditing election results and providing assistance in a recount. The techniques involve computerized image analysis of ballots, either for visualization or generating and validating a ballot definition file used to audit an election. Information associated with markings is extracted according to the image analysis process, associated, and aggregated for presentation in a logical way via, for example, a user interface for visualization. The data associated with the marking (e.g., ballot, election, physical location, etc.) are stored and can be easily called up in response to selection via the user interface.

[0011] Information is also extracted from a set of blank ballots to generate a ballot definition file, based on image analysis of the blank ballots or ballot styles. The ballot definition file can be used for a variety of purposes, e.g., generating machine-marked ballots for validation, for printing ballots for pre-election testing or actual election administration, and for evaluating and/or tabulating voter-marked ballots in support of auditing the election.

[0012] In one aspect, there is a method for displaying information associated with a set of ballots including one or more areas for expression of intent (e.g., voter intent). The method involves analyzing, with a computerized image analysis tool, the areas for expression of intent on the set of ballots. The

image analysis tool provides a score associated with the areas for expression of intent for one or more of the set of ballots. The method also involves displaying the analyzed areas on an image-display device according to a predetermined criterion. In some embodiments, the analyzed areas can be an actual marking made as an expression of intent, or a proxy marking that represents the expression of intent made on a ballot.

[0013] In some embodiments, the method involves receiving the set of ballots. The method can involve associating an area for expression of intent with a ballot on which the area appears and, in response to selection of at least one of the displayed areas, displaying the ballot associated with the selected area. The set of ballots can include paper ballots or computerized images of paper ballots. The method can, in some implementations, involve associating a location of a physical ballot with the corresponding image of the ballot and displaying the location of the physical ballot (e.g., for quick identification and/or location and subsequent inspection). In some embodiments, the method involves generating computerized images based on a corresponding set of paper ballots.

[0014] The areas for expression of voter intent can include a marking indicative of voter intent. Some implementations feature the predetermined criterion being associated with the score. The score can be based on a density (or density value) of a marking in an area for expression of intent. In some embodiments, the predetermined criterion is associated with a characteristic of an election. Exemplary characteristics include at least one of a voter group (e.g. absentee, early, provisional, overseas or Election Day voters), a race, a choice, a box-ID, a precinct, a district, or any combination of these. The predetermined criterion can be associated with a characteristic of a vote. Exemplary characteristics include at least one of an adjudicated vote, a marginal vote, an undervote, an overvote, an indication of uncaptured voter intent, a non-vote, or any combination of these. Displaying can involve grouping the one or more areas based on the characteristic of the vote or ballot associated with the respective one or more areas. The grouped areas can, in turn, be sorted according to a sorting criterion (e.g., descending by density score).

[0015] In some embodiments, displaying involves sorting the one or more areas for expression of intent into one or more categories based on the score for each area. The method can involve determining the number of areas in each category and/or determining whether a marking in an area constitutes a vote. Some implementations involve obscuring or not displaying a race associated with the area for expression of intent (e.g., to anonymize the election or candidate names).

[0016] Displaying, in some implementations, involves displaying the one or more areas sequentially based on the score associated with each area. In response to user-selection of an area, the method can involve displaying information associated with the area. Examples of information displayed in these embodiments include the area, a value indicative of the number of areas with scores greater than that of the user-selected area, the score associated with the area, or any combination thereof. The area for expression of intent can include at least one of a vote target or a contest zone. A vote target can be, for example, a Tillable oval or two markings connectable by a hand-drawn line representing a vote, and a contest zone can be, for example, a box bounding the vote target (or a plurality of vote targets constituting an election). In some implementations the location of a vote target is represented by x-y coordinates in a pixel reference frame of the center of the vote target. The location of a contest zone can be identified by, for example, coordinates of corners (e.g., top-left and lower-right) of the contest zone.

[0017] Some embodiments feature an interface associated with an area for expression of intent that is configured to receive user-supplied information. Examples of such interfaces include at least one of a user-Tillable field or a set of user-selectable choices or both. The method can involve updating a characteristic associated with the area for expression of intent based on the user-supplied information. For example, the user-supplied information can include at least one of a decision affecting the characteristic, a reason for the decision or both. The method can further involve generating and/or displaying a decision log based on the user-supplied information. Exemplary decision logs includes at least one of a ballot number associated with the area, the decision, the reason, a number of ballots associated with the decision, a number of ballots associated with the reason, or any combination of these.

[0018] In another aspect, there is a computer program product that is tangibly embodied in a non-transitory computer-readable storage medium that contains instructions operable to cause data processing apparatus to receive a set of ballots, each including one or more areas for expressions of intent. The instructions are also operable to cause data processing apparatus to analyze, with a computerized image analysis tool, the areas for expression of intent on the set of ballots. The image analysis tool provides a score associated with the areas for expression of intent for one or more of the set of ballots. The instructions are also operable to cause data processing apparatus to display the analyzed areas on an image-display device according to a predetermined criterion.

[0019] Another aspect features a computerized system for facilitating auditing an election. The system includes a user interface in communication with a data processor. The data processor includes an image analysis module operable to analyze one or more areas for expression of intent on a received set of ballots. The image analysis module provides a score associated with the areas for expression of intent for one or more of the set of ballots. The data processor also includes a sorting module in communication with the user interface for arranging the analyzed areas according to a predetermined criterion. The system also includes an interface in communication with the sorting module operable to communicate the arranged analyzed areas to a display device for display according to the predetermined criterion.

[0020] Yet another aspect features a method. The method involves receiving a computer-readable image of a ballot and analyzing the image of the ballot with a computerized image analysis tool to generate a ballot definition file associated with the ballot. The method also involves validating the ballot definition file.

[0021] In some embodiments, validating the ballot definition file involves generating a set of marked ballots based on a predetermined voting pattern and the ballot definition file and processing the set of marked ballots with a vote tabulator and the ballot definition file to provide a simulated election outcome based on the set of marked ballots. Validating can also involve comparing a predicted election outcome based on the predetermined voting pattern and the simulated election outcome. Generating the set of marked ballots can, in some implementations, involve machine-marking the ballots based on the ballot-definition file. Generating the set of

marked ballots can involve at least one of not voting, voting, overvoting, undervoting or a combination of these.

[0022] Some embodiments involve generating a first statement of votes cast associated with the predicted election outcome and a second statement of votes cast associated with the simulated election outcome. Comparing the predicted election outcome with the simulated election outcome involves, in some instances, comparing the first and second statements of votes cast. Comparing the first and second statements of votes cast can involve comparing a set of match points from the predicted election and a set of match points from the simulated election.

[0023] In some arrangements, the method further involves processing a set of voter-marked ballots with a first vote tabulator and the ballot definition file to determine a predicted election outcome, receiving an actual election outcome determined by a second vote tabulator processing the set of voter-marked ballots, and comparing the predicted election outcome and the actual election outcome. Comparing the predicted election outcome with the actual election outcome involves comparing a first statement of votes cast associated with the predicted election outcome and generated by the first vote tabulator and a second statement of votes cast associated with the actual election outcome and generated by the second vote tabulator. Comparing the first and second statements of votes cast involves comparing a set of match points from the predicted election and a set of match points from the actual election.

[0024] The generated ballot definition file can be based on the ballot style of the received ballot. Analyzing the image of the ballot involves, for example, determining a location of a contest zone, a vote target, or both, determining election information from the image, and associating at least one of a race name, a choice name, a voting rule, or any combination of these with the contest zone, the vote target, or both. The election information includes at least one of a precinct, a district, a jurisdiction name, an election date, or any combination of these. The method can also involve associating a ballot-style identifier and a ballot-side with the analyzed ballot. Some implementations of the method involve associating a location of a vote target with a timing mark on the ballot. The set of marked ballots can include voter-marked ballots.

[0025] Another aspect features a computer program product tangibly embodied in a non-transitory computer-readable storage medium containing instructions operable to cause data processing apparatus to receive a computer-readable image of a ballot, analyze the image of the ballot with a computerized image analysis tool to generate a ballot definition file associated with the ballot and validate the ballot definition file.

[0026] In some embodiments, the instructions operable to validate the ballot definition file include instructions operable to cause data processing apparatus to generate a set of marked ballots based on a predetermined voting pattern and the ballot definition file, process the set of marked ballots with a vote tabulator and the ballot definition file to provide a simulated election outcome based on the set of marked ballots and compare a predicted election outcome based on the predetermined voting pattern and the simulated election outcome. The computer program product can also include instructions operable to cause data processing apparatus to process a set of voter-marked ballots with a first vote tabulator and the ballot definition file to determine a predicted election outcome, receive an actual election outcome determined by a second vote tabulator processing the set of voter-marked ballots and compare the predicted election outcome and the actual election outcome.

[0027] In another aspect, there is a system for assessing an election result. The system includes an input module to receive a computer-readable image of a ballot and an image analysis module configured to analyze the image of the ballot. The system includes a file-generation module in communication with the image analysis module to generate a ballot-definition file based on an output of the image analysis module and a file validation module to validate the ballot definition file. In some embodiments, the system includes an interface to a vote tabulator for communicating the generated ballot definition file to the vote tabulator to facilitate processing a set of machine-marked ballots, voter-marked ballots, or both.

[0028] In some implementations, any of the above aspects can include any (or all) of the above-recited features.

[0029] These and other features will be more fully understood by reference to the following description and drawings, which are illustrative and not necessarily to scale.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. **1** is a block diagram of a system for visualizing an election.

[0031] FIG. **2** is a flow diagram illustrating an exemplary process for visualizing an election.

[0032] FIG. **3** is a screen capture of a user interface illustrating a partial set of displayed voter markings.

[0033] FIG. **4** is a screen capture of a user interface illustrating generation of a decision log.

[0034] FIG. **5** is a screen capture of a user interface illustrating a set of voter markings subject to adjustment.

[0035] FIG. **6** is a conceptual block diagram of a system for generating a ballot definition file from a ballot.

[0036] FIG. **7** is a block diagram of a system for validating a ballot definition file.

[0037] FIG. **8** is a block diagram of a system for auditing an election with a validated ballot definition file.

[0038] FIG. **9** is a flow chart of an exemplary process for generating a ballot definition file.

[0039] FIG. **10** is a flow chart of an exemplary process for validating a ballot definition file.

[0040] FIG. **11** is a flow chart of an exemplary process for auditing an election.

DETAILED DESCRIPTION

[0041] FIG. **1** is a block diagram of a system **100** for visualizing an election. The system **100** includes an image analysis tool **105** and a display **110** in communication with the image analysis tool **105**. The image analysis tool **105** can be hardware-based or software-based and in communication with a computer processor (not shown), a computer memory (not shown), and/or a communication bus (not shown). The image analysis tool **105** receives as input a set of ballots **115**. The set of ballots **115** includes individual voter-marked ballots **115***a*-**115***d*.

[0042] The set of ballots **115** can be either paper ballots or images of paper ballots. The images of paper ballots can be, for example, in PDF or JPEG format. In embodiments in which the set of ballots **115** are paper ballots, a ballot-imaging tool (not shown) prepares images of the paper ballots, e.g., in PDF or JPEG format, by scanning and/or processing the

paper ballots. In some embodiments, the ballot images are created or prepared contemporaneously when the ballots are scanned to record a voter's votes, rather than being batch-scanned after the paper ballots are collected. For example, an imaging sub-routine associated with the ballot scanner or vote reader can be used to prepare the ballot image, and the images can be collected from the ballot scanners or vote readers for visualization. As used herein, a ballot refers to an image of a paper ballot unless otherwise indicated. The image analysis tool **105** evaluates each individual voter-marked ballot **115***a*-**115***d*, as discussed in more detail below. The image analysis tool **105** can evaluate, group, sort, or order the voter-marked ballots **115***a*-**115***d* (or portions thereof) according to a predetermined evaluation, grouping, sorting, or ordering criterion (or criteria).

[0043] In some embodiments, the image analysis tool **105** evaluates an individual choice on each voter-marked ballot **115***a*-**115***d* and groups, sorts, or orders the set of ballots **115** on an individual choice basis. Generally, an election refers to the set of contests within an election jurisdiction (e.g. county). Contests are comprised of a set of choices as, for example between candidates or between referendum questions. A contest is generally characterized at least by a name (e.g., presidential, senatorial, etc.), the selectable options (e.g., candidates or decisions) and the voting rules associated with the options (e.g., "vote for only one," "vote for no more than two," etc.).

[0044] FIG. **2** is a flow diagram illustrating an exemplary process **200** for visualizing the votes for a choice ("Claire L. Janowski) within a contest ("State Representative"). The process **200** begins with a set of voter-marked ballots **205**. The set of voter-marked ballots **205** includes ballot **205***a*. The ballot **205***a* can be a paper ballot or an image of a paper ballot. The ballot **205***a* is associated with information **210** related to the paper ballot corresponding to the image of ballot **205***a*. The information **210** is referred to as the "Ballot File ID" in FIG. **2** and includes "Box ID" and "Sequence #" information. The computer file name of the ballot image is derived by appending the image type to the Ballot File ID, for example AB-2+0127.bmp. The Box ID associated with the ballot **205***a* is "AB-2," and the Sequence # associated with the ballot **205***a* is +0127 indicating the paper ballot associated with image **205***a* is stored in the physical box of ballots labeled AB-2 in position **127** counted from the front of the box. The information **210** allows the paper ballot to be quickly identified, located, and consulted, if necessary, upon review of the ballot **205***a* revealing manual inspection or analysis is required or desired.

[0045] The ballot **205***a* includes an area **215** that includes five races **220***a*-**220***e*. The horizontal axis **225***a* of the area **215** represents the office and the vertical axis **225***b* represents the party of the candidates. The individual boxes **230** in area **215** are or contain areas for indication of voter intent. As illustrated, a box **235** containing a vote target **240** (e.g., a marked oval) is called out from the area **215**. The vote target **240** is the area on the ballot **205***a* in which a voter can provide an indicia of intent, e.g., by marking with a marking utensil such as a pencil, pen, or marker. The box **235** represents a vote for the Democratic candidate Claire L. Janowski running in race **220***d* (State Representative). The race **220***d* is identified as "Race **20**" on the ballot **205***a*.

[0046] An image analysis tool (not shown), such as, e.g., the image analysis tool **105** of FIG. **1**, evaluates the ballot **205***a*. In particular, the image analysis tool extracts the vote target **240** from the ballot **205***a* and can display the extracted vote target **240** in a user interface **245**. The image analysis tool calculates a density value for each of the boxes **230** in the area **215** and each of the elections (not indicated) on the ballot **205***a*. With respect to the race **220***d*, the image analysis tool determined that the density associated with the vote target **240** in box **235** has a value of 56.86, as shown in the user interface **245**. The density typically indicates the degree of confidence that the image analysis tool assigns to a given vote target (e.g., higher density scores indicate higher confidence that the voter has expressed their intent unambiguously). The image analysis tool calculates density of the vote target (e.g. a rectangular box (not shown) that bounds the vote target **240**) by measuring the percent coverage and darkness of the mark in the vote target **240**. Thus, for example, a vote target **240** that is completely filled in with a light pencil will register a lower density than another vote target **240** completely filled in with a black, felt-tip pen. The rectangular box **235** is sometimes called a "contest zone." In some embodiments, the image analysis tool can find and/or evaluate markings outside the vote target **240** but within the contest zone **235**.

[0047] After evaluating the ballot **205***a*, the image analysis tool extracts vote targets **250** associated with the same choice (e.g., **235**) from the other ballots in the set of ballots **205**. The extracted vote targets **250** associated with choice **235** are displayed in a user interface window **255** along with the extracted vote target **240**. In some embodiments a proxy mark is displayed instead of the actual mark made by the voter. When a proxy mark is shown, a user can click on the proxy mark and the actual ballot, showing the actual mark made by the voter, can be viewed. The extracted vote targets **240**, **250** as shown in user interface window **255** are generally organized by the order in which the vote targets were extracted (e.g., in the order in which the images of the set of ballots were analyzed). Typically, after all the vote targets **240**, **250** have been extracted, the vote targets **240**, **250** can be sorted or organized, e.g., as shown in the user interface window **260**. In some embodiments, the vote targets **240**, **250** are sorted in descending order according to the density associated with the vote target **240**, **250**, as calculated or determined by the image analysis tool.

[0048] For example, the user interface window **260** includes the vote target **240** associated with the ballot **205***a*, as well as other extracted vote targets **250**. The user interface **260** provides a quick and intuitive view of an election (e.g., the votes cast for Claire L. Janowski in race **220***d*). The user interface window **260** is, in some embodiments, interactive. For example, in response to a user selection (e.g., by hovering a pointing device or element **265** over the portion of the user interface window **260** coincident with the extracted vote target **240**), an information field **270** is displayed. In some embodiments, the candidate names are not presented or are obscured or covered to allow the votes to be evaluated without knowledge of how a change or decision will benefit or detract from a candidate's vote total.

[0049] As illustrated, the information field **270** includes four subfields **275***a*-**275***d*. The subfield **275***a* identifies the "Sequence #" of the vote target **240** among the set of extracted vote targets **250** shown in the user interface window **260**. As illustrated, the vote target **240** has a value for "Sequence #" of 3, indicating the vote target **240** has the third-highest score in user interface window **260** (e.g., or the third-highest density score). The subfield **275***b* identifies the density associated with the vote target **240**, as calculated or determined by the image analysis tool. The subfield **275***c* contains an indicator

of the "Race." The value of the "Race" subfield **275***c* as illustrated is "20 Janowski" indicating the user interface window **260** is associated with the votes for Claire L. Janowski in race **220***d*. The subfield **275***d* contains an indicator of the "Location." The value of the "Location" subfield **275***d* provides an indication of the physical location of the ballot **205***a* containing the vote target **240**, in this case at position **127** in the box labeled AB-2. Thus, if the vote target **240** is of interest, the physical location of the paper ballot corresponding to the image of ballot **205***a* can be quickly located for further examination or evaluation. In some embodiments, in response to a user selection (e.g., a mouse-click on the portion of the user interface window **260** coincident with the extracted vote target **240**), an image of the ballot **205***a* is displayed.

[0050] FIG. **3** is a screen capture of a user interface **300** illustrating a partial set **305** of displayed voter markings. The user interface **300** includes a first area **310***a*, a second area **310***b*, and a third area **310***c*. The first area **310***a* displays a plurality of images **315***a* of vote targets, e.g., as discussed above with respect to FIG. **2**. The plurality of images **315***a* in the first area **310***a* (like the images **315***b* in the second area **310***b* and the images **315***c* in the third area **310***c*) are sorted in descending order by the score associated with each vote target. For example, as illustrated, the vote **320***a* is associated with a density value of 94.65 and is assigned a "Seq." number of 1, indicating vote **320***a* has the highest score. The information **325***a* associated with the vote **320***a* is displayed, for example, in response to hovering a mouse pointer over the part of the first area **310***a* collocated with the vote **320***a*.

[0051] The second area **310***b* displays a plurality of images **315***b* of vote targets. The second area **310***b* also includes a transition region **330**. The transition region **330** illustrates the transition from markings **335***a* that indicate a voter's intent unambiguously and a vote target **335***b* that does not necessarily indicate voter intent. The transition region **330** typically appears around threshold density values. For example, in some embodiments, images of vote targets having a density above a particular threshold value are determined to be indications of voter intent to cast a vote (e.g., votes) and images of vote targets below the threshold value (or a second, usually lower threshold density value) are determined to be indications of voter intent to not cast a vote. Density values near these thresholds are typically associated with unclear markings or unclear indications of voter intent. For example, the vote targets **335***c* are not filled-in ovals, and therefore, may or may not be counted by a vote tabulator (not shown) according to the tabulator's logic. An advantage of the user interface **300** is quick and visual identification of votes in the transition region **335**. By sorting the images **315***a*-**315***c* in descending order according to the score, potentially problematic votes can be isolated and identified quickly. Moreover, because the images of the vote targets in the interface **300** are each associated with the physical location of a ballot, selection of a vote target (e.g., by hovering a mouse pointer over an image) provides information sufficient to locate the physical ballot quickly for manual inspection and/or determination of voter intent based on context and/or other markings on the ballot.

[0052] The third area **310***c* displays a plurality of images **315***c* of vote targets. The third area **310***c* typically displays vote targets that do not represent votes for a particular candidate or choice in an election. Like the images **315***a* and **315***b*, each of the images of vote targets **315***c* is associated with a density value or score and a Sequence identifier, identifying its relative position in the set of vote targets. For example, the vote target **320***c* is associated with a density of 4.87 and a Sequence No. of 13,393, shown in information **325***c*. The non-zero density value of vote target **320***c* is based in part on the image analysis tool including the pixels representing the oval or vote target in the density calculation. As discussed above, vote targets **315***c* having density scores below a threshold value are generally determined to be non-votes because non-votes typically have density values that fall below the threshold. The last vote target **340** in the third area **310***c* has a density score of 1.66 and a Sequence No. of 13,620, as shown in pop-up information **345**. The information **345** quickly provides an indication of the number of ballots displayed for the election shown in the user interface **300**. In this case, the user interface represents 13,620 total ballots. In general, the information **345** associated with the lowest-scoring vote target **340** should match the number of ballots counted by the vote tabulator.

[0053] Hovering a mouse over an area of the interface **300** quickly tells the user how many votes are in each area **310***a*-**310***c*. Those of skill will appreciate that there are additional ways to communicate how many vote targets **315***a*-**315***c* exist in each area **310***a*-**310***c*. For example, the last vote in each area (e.g., the vote target with the lowest score above the applicable threshold) can be used to determine the number of votes in that area **310***a*-**310***c*, e.g., by subtraction. Some embodiments feature the interface **300** providing information (not shown) indicating the summed or total number of votes in each area **310***a*-**310***c*.

[0054] FIG. **4** is a screen capture of a user interface **400** illustrating generation of a decision log **405**. Additionally, the user interface **400** demonstrates the utility of quickly and simply visualizing areas for indication of voter intent as a way to verify and audit election results and is based on an actual audit of the 2008 General Election as certified by the Registrar of Voters in Vernon, Conn. The user interface **400** illustrates how the system **100** of FIG. **1** can assist an election department or an independent auditor in verifying the results of an election before the results are certified.

[0055] The interface **400** displays a plurality of images **410** of vote targets. The images **410** of vote targets are sorted in descending order according to the density value or score associated with each vote target. The interface **400** includes a vote target **415**, at Sequence No. 4,304 in the set of images **410**. The vote target **415** represents the total number of votes an election board certified for a particular candidate, in this case 4,034 votes (indicated as "Official Certified Results"). In this case, the number of votes, 4,034, was erroneous. As can be seen from the interface **400**, however, the "Official Certified Results" appear to have missed a set **420** of additional votes intended for the particular candidate. The error of the Official Certified Results is almost immediately apparent based on the arrangement of vote targets **420** that appear after Sequence No. 4,034 and before the vote target **425** associated with Sequence No. 4,623. The image analysis tool (not shown) determined vote target **425** has the lowest density score above the threshold value of markings to be counted as votes. Thus, on initial inspection, there is a discrepancy of 589 votes between the certified results and the actual number of votes preliminarily identified.

[0056] The interface **400** also illustrates generation of the decision log **405**. The decision log includes nine decision entries **440***a*-**440***i*, each associated with a vote target **445***a*-**445***i* in the set of vote targets **410**. Each of the vote targets

445*a*-**445***i* contains some type of marking that the vote tabulator did not record as an intended vote as shown by their appearance after vote target **425**, Sequence No. 4,623, which is the last image having a density score above threshold. After manual inspection, vote targets **445***a*, **445***g*, and **445***i* were determined to not be votes. After the ballot image (not shown) associated with each of vote targets **445***a*, **445***g*, and **445***i* was selected (e.g., by a mouse-click on the vote targets **445***a*, **445***g*, and **445***i*) and the determination of "non-vote" was made, information associated with the reason for the determination was added to a field, either by user selection or free-text entry, was added or associated with the ballot. For example, vote target **445***a* was determined to be a non-vote whose marking was associated with an erasure, so the notation "Erasure" was added to the information field associated with the ballot. For vote targets **445***g* and **445***i*, the marking was determined to be a hesitation mark, not an indication of intent, and the notation "Hesitation Mark" was added to the information field associated with each ballot.

[0057] The information from the information field associated with the ballots is used to populate the decision log **405** (either automatically or in response to a user prompt or command to generate the decision log **405**). For example, the determination of "Non Vote" and the indication of "Erasure" associated with the vote target **445***a* is shown as Entry No. 1 (**440***a*) in the decision log **405**. Similarly, the determination of "Non Vote" and the indication of "Hesitation Mark" associated with the vote targets **445***g* and **445***i* is shown, respectively, as Entry Nos. 7 (**440***g*) and 9 on the decision log **405** (**440***i*).

[0058] Moreover, the interface **400** can be used to change the status of a vote from non-vote to an affirmative or adjudicated vote. For example, each of the vote targets **445***b*-**445***f* and **445***h*, upon examination of the ballot or ballot image associated with each vote target **445***b*-**445***f* and **445***h*, was determined to constitute a vote based on clear intent. The information field associated with each respective ballot was updated or notated to indicate the determination of "Vote" and to indicate "Clear Intent" as the rationale for changing from non-vote to adjudicated vote. The information fields associated with each ballot was then used to populate the decision log **405**. For example, the determination of "Vote" and the indication of "Clear Intent" associated with each of the vote targets **445***b*-**445***f* and **445***h* is shown, respectively, as Entry Nos. 2-6 (decision entries **440***b*-**440***f*) and Entry No. 8 (decision entry **440***h*). The decision log **405** provides an additional safeguard and record of decisions made by election officials in assessing the votes in the election. The order of the decision entries **440***a*-**440***i* on the decision log **405** corresponds to the order (e.g., descending order according to score) the associated vote targets **445***a*-**445***i* appear in the interface **400**.

[0059] The decision log **405** includes a "Final Vote" field **450** that has a value of 4,629 to reflect the sum of adjudicated vote total associated with vote target **425** (e.g., 4,623) and the manually-determined votes added based on the decisions (e.g., 6 additional votes **445***b*-**445***f* and **445***h*) reflected in the decision log **405**. As a result of using interface **400**, the correct number of votes for the candidate should have been 4,629, rather than the 4,034 votes certified as the election result. In this case, the certified results erroneously omitted **595** votes. The error was determined, after use of the visualization tools described here, to be the result of a manual error in transcribing the count of votes from a vote reader's poll tape to the official Head Moderator's Report that was filed with the Connecticut Secretary of State.

[0060] FIG. **5** is a screen capture of a user interface **500** illustrating a set of voter markings subject to adjustment. The user interface **500** includes a first portion **505***a* containing vote targets **510***a* of adjudicated votes, a second portion **505***b* containing vote targets **510***b* of under votes and a third portion **505***c* containing vote targets **510***c* of overvotes. In the illustrated embodiment, the vote targets **510***a*-**510***c* are associated with the "No" choice in contest **520**, titled "Ballot Question No. 1" on ballot **515**. The contest **520** refers to "Ballot Question No. 1" is "Shall there be a Constitutional Convention to amend or revise the Constitution of the State?" and the voting rules associated with election require only one vote, either by filling the "Yes" oval **525***a* or the "No" oval **525***b*.

[0061] In general, the sum of the vote targets **510***a*-**510***c* in each portion **505***a*-**505***c* should be equal to the number of ballots visualized. The number of vote targets in each area **505***a*-**505***c* is denoted, respectively, as "=n,nn**1**" **507***a*, "=n, nn**2**" **507***b*, and "=n,nn**3**" **507***c*. A decision process allows votes from one portion (e.g., vote targets **510***b* from the second portion **505***b*) to be moved to another portion (e.g., added to the vote targets **510***c* of the third portion **505***c*). For example, the second portion **505***b* contains a vote target **530** of interest. The vote target **530** is associated with ballot **515** and, specifically, contest **520**. The marking **535** in the vote target **530** reflects the "No" oval **525***b* from contest **520** on the ballot **515** (rotated 90° counter-clockwise). In response to a user selection (e.g., hovering a mouse pointer over or clicking on vote target **530**), the image of ballot **515** is displayed. Further examination reveals the "Yes" oval **525***a* completely filled and the "No" oval **525***b* only partially filled. Based on this examination and the voting rules or logic (e.g., only one vote for contest **520**), the vote target **525***b* is ambiguous and might be adjudicated by a canvassing board either as an indication of voter intent, which would result in invalidating the "Yes" vote at **525***a* or, alternatively as a hesitation mark that did not indicate voter intent for the choice "No" and, therefore, recording the "Yes" vote at **525***a* as the voter's true intent. Although not illustrated, should the canvassing board ascribe voter intent to **525***b*, the rationale or explanation for moving vote target **530** from the second portion **505***b* to the third portion **505***c* can be added to an information field associated with the ballot **515** and used, if desired, to populate a decision log (not shown).

[0062] In some embodiments, the vote targets **510***a*-**510***c* are categorized, grouped, or assigned to the respective portions **505***a*-**505***c* based on a predetermined criterion (or criteria). Examples of such criteria include whether the density value of a particular vote target exceeds or falls below a predetermined threshold, whether a vote target falls between values associated with undervotes or overvotes, or some combination thereof to facilitate automated organization of vote targets into categories. A purpose of the grouping is to quickly organize potential votes, non-votes, and under-votes together and/or focus the attention of human judges on potentially ambiguous expressions of voter intent to significantly reduce the time needed to determine the vote count. In some embodiments, the vote targets **510***a*-**510***c* in each portion **505***a*-**505***c* are sorted according to their score (e.g., a density score), but this is not required.

[0063] FIG. **6** is a conceptual block diagram of a system **600** for generating a ballot definition file **605** from a ballot

610*a* or a ballot **610***b*. The system **600** allows testing of a voting system prior to Election Day with a set of pre-marked test ballots having a known result and that correspond to the voting system's memory card ballot style configuration and independently auditing and election outcome with a validated ballot definition file. For some jurisdictions, there are hundreds or thousands of ballot styles, each unique depending on the combination of contests and the choice positions presented thereon. Due to the variability in ballot styles, it can be difficult, costly, and time-consuming to consistently hand-mark a unique ballot style for testing purposes.

[0064] The ballot **610***a* is associated with a first ballot style, and the ballot **610***b* is associated with a second ballot style. In general, a ballot style refers to the combination and placement of races and the order of choices in an election. In some embodiments, the combination and placement of races and choices is unique. For example, the ballot **610***a* includes a location **635***a* that contains a Contest **645***a* for "State Senator District **3**" and a Contest **645***b* for "Justice of the Supreme Court". The ballot **610***b* also includes a corresponding location **635***b* that depicts a different set of Contests **645***c* and **645***d*.

[0065] The system **600** receives as input the ballot style of ballot **610***a* and of ballot **610***b*. In some embodiments, the ballots **610***a*-**610***b* are received as ballot images and the ballot style is extracted and associated with an identifier. For example, the ballot images for ballots **610***a*-**610***b* can be received as PDF files. The ballot style information can be used to print physical (e.g., paper) ballots for the purpose of facilitating marking of the ballots (e.g., as part of conducting an election and/or for validating the ballot definition file **605**).

[0066] The system **600** includes a module **640** that generates the ballot definition **605** based on the received ballot style information associated with each of the ballots **610***a*-**610***b*. In some embodiments, the module **640** includes an image-analysis tool that analyzes, with a computing device, the ballots **610***a*-**610***b* to generate the ballot definition file **605**. For example, the image-analysis tool can determine, based on image analysis, the elements of the ballot style associated with each ballot type **610***a*-**610***b*.

[0067] The ballot definition file **605** can include a variety of information about the ballots **610***a*-**610***b*. For example, the ballot definition file **605** can include the elements set forth in the table below, with reference to the location **615***a* of ballot **610***a*:

Element	Description	Example	Reference
Jurisdiction	The territorial extent to which an election applies	Leon County, Florida	625b
Election & Date	The name of the election and the date on which the election was conducted	"General Election" Nov. 4, 2008	625a 625c
Contest Name(s)	The electoral contest(s) within an election	"State Senator" "Justice of the Supreme Court"	645a-d
Candidate/Choice Name(s)	The names of the candidates/choices running in each contest 645a. In location 615a, the candidate names are "Charles S. Dean" and "Suzan L. R. Franks"	"Charles S. Dean" "Suzan L. R. Franks" "Yes" "No"	650a 650b, c, d
Vote Rules	Information codifying the number of votes a voter may cast in a contest.	"Vote for One"	620a
XY Coordinates of Vote Targets	The x- and y- coordinates for each vote target 645d associated with the contest relative to a reference coordinate system. The coordinates can be represented, in some embodiments, as pixel coordinates.	13, 2	Not shown
Precinct/District	A geographic subset of the election jurisdiction.	"5201" "2507"	635a 635b
Ballot Style Number	A numeric identifier that is typically encoded into a machine-readable dash-code or barcode. This identifier tells the vote reader which interpretation to use for this ballot.	Not human readable. In this embodiment, the dashes along the bottom of the ballot encode the Ballot Style number.	660a, b

[0068] The elements of the ballot definition file **605** can be stored in any format suitable for allowing ballots to be printed, machine-marked, and/or for tabulating votes. The various uses for the generated ballot definition file **605** are discussed in more detail below.

[0069] FIG. **7** is a conceptual block diagram of a system **700** for validating a ballot definition file **750**. The system **700** includes a first portion **705** typically performed by an election department **710** and a second portion **715** typically performed by an entity **720** seeking to validate and/or audit an election such as, for example, Clear Ballot Group of Boston, Mass. (or its customers) or an election watchdog.

[0070] The first portion **705** includes an election management system **725** that is used to administer an election. In one embodiment, the election management system **725** is used to create a set **730** of ballot definition files that are used to program the vote tabulators. For example, the set **730** of ballot

definition files can be stored on one or more memory cards (not shown) and provided to a set of scanners and/or vote tabulators **735** for interpreting and/or counting marked ballots. The election management system **725** is also associated with a set **740** of ballot styles (e.g., saved as PDF files). The set **740** of ballot styles can be used, for example, to print ballots for conducting the election. As illustrated, the set **740** of ballot styles is provided the entity **720**. The entity **720** can use the set **740** of ballot styles as an input to a module **745** for generating a set **750** of one or more ballot definition files, based on the set **740** of ballot styles. The set **750** of ballot definition files is created and validated independently of the set **730** of ballot definition files used by the election department **710**. In some embodiments, each of the set **750** of ballot definition files corresponds to at least one member of the set **730** of ballot definition files. The validation of the files in the set **750** typically proceeds on a file-by-file basis, but this is not required.

[0071] The set **750** of ballot definition files can be provided to a ballot-marking module **755** that includes a database **760***a* of marking patterns and an implementation module **760***b* that prepares or generates a set **765** of marked ballots corresponding to the applicable marking patterns for a simulated election. The set **765** of marked ballots can either be ballot images corresponding to the simulated election or physical ballots prepared based on ballot images. The set **765** of marked ballots is based on the database **760***a* of marking patterns reflecting the applicable voting logic or rules and a predicted or controlled election outcome. As illustrated, the set **765** of marked-ballots is represented as a set of ballot images that can be converted into machine-marked paper ballots **770** by a ballot-on-demand printer **775** printing the set **765** on ballot-stock paper. In some embodiments, the marking module **755** marks the ballots with varying darkness gradations to simulate actual election conditions. Moreover, the module **755** can simulate voter-marked ballots (e.g., using an "X" shape instead of a darkened oval). Moreover, the marking module **755** can implement over-votes, blank votes, undervotes, or combinations of valid votes, based on the voting pattern and/or a voting rule or voting rule logic.

[0072] The process for validating the set **750** of ballot definition files involves processing a set of machine-generated ballot images **765** with a second vote tabulator **785**. The machine-generated ballot images **765** were created by using the set of ballot definition files **750** and a pre-determined pattern of marking the ballots **760***a*. The ballot images have a pre-determined Statement of Votes Cast **765** ("SOVC"). Validating the internal consistency of the set **750** of ballot definition files involves comparing the SOVC **765** to SOVC **790**, the output of the independent vote tabulator **785** as calculated by the entity **720**.

[0073] The process to ensure that the voting system **705** and the audit system **715** are capable of producing identical results involves validating the set **750** of ballot definition files against the set **730** memory card versions of the ballot definition files by counting the votes from a set of marked paper ballots **770** using the tabulator **735** of the election department **710** to produce a Statement of Votes Cast **780** ("SOVC **780**"). In some embodiments, the ballots in **770** can be printed on ballot stock by a "ballot-on-demand printer" or, in another embodiment, marked by hand by using the images from **765** as a template. Typically, the election department **710** performs this step. SOVC **780** is calculated based on the election department's equipment (e.g., scanners and vote tabulator **735**) and the election department's ballot definition file **730** to determine a simulated election outcome based on readings or analysis of the machine-marked paper ballots **770**. Provided the markings are well formed, the results from **780** should exactly match the result from **790**.

[0074] The comparison of SOVC **780** and SOVC **790** results in a comparison value (not shown). If the comparison value exceeds a predetermined threshold (e.g., 95%), the set **750** of ballot definition files is deemed to acceptably represent (e.g., as a proxy for) the set **730** of ballot definition files the election department **710** uses to conduct an actual election on a file-by-file basis or one-to-one correspondence. To calculate the comparison value, each member of a set (not shown) of match points from SOVC **780** is compared to a corresponding match point from SOVC **790**. In some embodiments, a match point from either SOVC **780** or SOVC **790** includes certain information such as, for example, a vote count associated with a choice, a precinct, and/or a voter group.

[0075] Additionally, the SOVC **790** can be compared to information associated with the set **765** of marked ballots. The set **765** of marked ballots represents the output of the marking module **755** and, ideally, the information associated with the set **765** should be equal to the information determined in the SOVC **790** by tabulating the set **765** of ballots. In such a configuration, this process provides a quality check internal to the entity **720**. If either the comparison between SOVC **790** and SOVC **780** or the information associated with the set **765** of marked ballots falls below an acceptable threshold, the set **750** of ballot definition files is deemed to not adequately or accurately represent the set **730** of ballot definition files. The ballot definition file from the set **750** can be evaluated, and the validation process can then be performed again, possibly with changed parameters of the image analysis device/tool or the generation module **745** that creates the ballot definition file.

[0076] FIG. **8** is a conceptual block diagram of a system **800** for auditing an election with a validated ballot definition file **850**. The system **800** includes a first portion **805** typically performed by an election department **810** and a second portion **815** typically performed by an entity **820** seeking to audit an election result such as, for example, Clear Ballot Group of Boston, Mass. (or its customers) or an election watch-dog.

[0077] The first portion **805** of FIG. **8** is conceptually similar to the first portion **705** of FIG. **7** in that the first portion **805** includes an election management system **825** associated with a set **830** of ballot definition files used to administer the election. The set **830** of ballot definition files can be stored on one or more memory cards (not shown) and provide to a set of scanners and/or vote tabulators **835** for interpreting and/or counting marked ballots **860**. A set **840** of ballot styles is used by a ballot printing element **845** to generate blank ballots (not shown) on which voters will mark their intent to create a collection **860** of voter-marked ballots. Like FIG. **7**, a set of ballot styles **840** is provided to the entity **820** for generation and validation of a set **850** of ballot definition files by a module **855** as described with respect to FIG. **7**. The collection **860** of voter-marked ballots is processed by the tabulator **835** of the election department **810** to determine a Statement of Votes Cast **865** ("SOVC **865**"). The SOVC **865** represents the initial determination of the results of the elections on the collection **860** of voter-marked ballots and is referred to as the initial actual election outcome.

[0078] To facilitate auditing the election, the collection **860** of voter-marked ballots (e.g., either ballot images or paper

ballots that are converted to ballot images) is provided to the system supplied by entity **820**. The collection **860** of voter-marked ballots is then processed by a vote tabulator **870** associated with the entity **820**. The vote tabulator **870** processes the voter-marked ballots **860** using the validated ballot definition file **850** associated with the particular ballot style **840** represented by the voter-marked ballots **860**. In some embodiments, the vote tabulator **870** determines the particular ballot definition file from the set **850** based on a preliminary analysis of the voter-marked ballots. The vote tabulator **870** provides as output a Statement of Votes Cast **875** ("SOVC **875**") based on the vote tabulator's **870** processing of the voter-marked ballots and the ballot definition file **850**. The SOVC **875** is, in some embodiments, referred to as a predicted election outcome.

[0079] Auditing an election involves comparing the SOVC **865** that the vote tabulator **835** of the election department **810** produces and the SOVC **875** that the vote tabulator **870** of the entity **820** produces. The comparison of SOVC **865** and SOVC **875** results in a comparison value (not shown). The comparison value is generally directly proportional to the confidence in the election outcome represented by SOVC **865**. More specifically, if the independently-generated ballot definition file **850**, which was previously validated, used to process the collection **860** of voter marked ballots produces a SOVC **875** that is dramatically different than SOVC **865**, the entity **820** (or others) may have reason to question or challenge whether the actual election outcome reflects actual voter intent or the correct number of votes. Conversely, if the SOVC **875** closely matches the SOVC **865**, the degree of confidence increases.

[0080] To calculate the comparison value, each member of a set (not shown) of match points from SOVC **865** is compared to a corresponding match point from SOVC **875**. In some embodiments, a match point from either SOVC **865** or SOVC **875** includes certain information such as, for example, a vote count associated with a choice, a precinct, and/or a voter group. If there are discrepancies in the match-points between SOVC **865** and SOVC **875**, the individual ballots giving rise to the discrepancies can be quickly obtained and visualized using, for example, the visualization tools described and shown in FIGS. **1-5**. This allows election monitors and/or auditors to quickly isolate and diagnose discrepancies and facilitate faster, less expensive, and more efficient recounts of the election outcome if necessary.

[0081] FIG. **9** is a flow chart **900** of an exemplary process for generating a ballot definition file. The flow chart **900** illustrates a process that can be executed or carried out by, for example, the module **745** of FIG. **7** or the module **855** of FIG. **8**. Moreover, the flow chart **900** represents a simplified form of the process, and additional details or information from a ballot can be analyzed and/or determined from a particular ballot image for storing in a ballot definition file.

[0082] The process involves receiving a ballot image (step **905**) that is associated with a particular ballot style. As discussed above, a ballot style is a combination and placement of races and choices in an election on a particular date. The ballot image is analyzed (step **910**) to extract and process information. The ballot image can be analyzed by an image-processing tool designed to read and extract information from the ballot image. An exemplary sub-routine **915** is depicted for extracting information from the ballot image. The image analysis tool determines election information (step **920**) and locates a contest zone and/or vote target on the ballot image (step **925**). Exemplary election information includes the jurisdiction represented by the ballot style, the election identity and date, the contest name, the candidate names, the voting rules associated with the contest, and/or the precinct. The contest zone includes, for example, the region on a ballot image in which certain election information is located or positioned. For example, the election identity, contest name, candidate names, and voting rules can be located in or near the contest zone. The x-y coordinates, relative to a reference frame, of the vote targets is also determined. In some embodiments, the x-y coordinates are indexed by timing marks appearing along an edge or edges of the ballot image, but this is not required.

[0083] After the information has been extracted by the image analysis tool in steps **920-925**, the extracted information is associated (step **930**) to define a ballot style (step **935**). Analysis of the ballot image (step **910**) and/or sub-routine **915** results in generation of a ballot definition file (step **940**). After the ballot definition file is generated, the ballot definition file is validated (step **945**), for example, using the process described with respect to FIGS. **7** and **10**.

[0084] FIG. **10** is a flow chart **1000** of an exemplary process for validating a ballot definition file. The flow chart **1000** can depict, for example, the validation step (step **945**) of FIG. **9**. The process involves receiving a voting pattern and ballot definition file (step **1005**). The voting pattern provides an expected outcome of one or more elections. The voting pattern can include, for example, the number of votes for each candidate in a simulated election. For example, the voting pattern can specify that Candidate A will receive 15 votes and Candidate B will receive 25 votes as the election outcome. In some embodiments, the voting pattern specifies how each ballot should be machine-marked such that the combination of machine-marked ballots results in Candidate A receiving 15 votes and Candidate B receiving 25 votes. Where a ballot contains more than one election, the number of possible voting pattern combinations increases. The ballot definition file received at this step **1005** is a ballot definition file generated from a ballot image independently of the ballot definition file an election department actually uses the conduct the election. Moreover, the received ballot definition file is the ballot definition file being validated.

[0085] The validation process involves machine-marking the ballots according to the voting pattern and based on the ballot definition file (step **1010**). For example, machine marking the ballots involves evaluating the voting pattern, in conjunction with the ballot definition file, to determine how the ballots are to be marked to satisfy the voting pattern and then marking the ballots to satisfy the voting pattern. In some embodiments, the location of marks representing expressions of voter intent corresponds to the x-y coordinate of the vote target information for the candidate who is to receive the vote. The x-y coordinate of the vote target is specified in the ballot definition file. A marking is made over the vote target location based on the logic specified in the voting pattern. The process involves providing the set of machine-marked ballots (either paper ballots or ballot images) and the ballot definition file being validated to a vote tabulator (step **1015**).

[0086] The vote tabulator scans and tabulates a simulated election result by evaluating the machine-marked ballots using the ballot definition file to provide a simulated election outcome (step **1020**). In some embodiments, the simulated election outcome is in the form of a Statement of Votes Cast generated by the vote tabulator. The simulated election out-

come from step **1020** is compared with the voting pattern information from step **1005**, also called a predicted election outcome, in step **1025**. In some embodiments, the predicted election outcome is in the form of a Statement of Votes Cast. If the predicted election outcome and the simulated election outcome acceptably match (step **1025**) according to an acceptability criterion or threshold, the ballot definition file is deemed to validly represent the ballot definition file the election department will use to conduct the election (step **1030**). If the predicted election outcome and the simulated election outcome do not acceptably match in step **1025**, the ballot definition file is deemed to not validly represent the election department's ballot definition file (step **1035**), and the process returns to step **910** of FIG. **9** for regeneration of a new ballot definition file (e.g., based on changed or updated parameters to the image analysis tool or module generating the ballot definition file).

[0087] FIG. **11** is a flow chart **1100** of an exemplary process for auditing an election. The process involves receiving a set of voter-marked ballots (step **1105**). The voter-marked ballots can be either ballot images or physical ballots. In embodiments in which the voter-marked ballots are physical ballots, the process involves converting the physical ballots to ballot images (not shown). An exemplary format for the ballot images is either JPG or PDF format. The process involves receiving a validated ballot definition file (step **1110**), for example, a ballot definition file generated by the process of FIG. **9** and validated by the process of FIG. **10**. The validated ballot definition file is created independently of knowledge of the underlying ballot definition file of the election department and is based on an image of a ballot or ballot style. The process involves providing the voter-marked ballot images and the validated ballot definition file to a vote tabulator (step **1115**). The vote tabulator examines and evaluates the voter-marked ballots using the validated ballot definition file to produce a predicted election outcome (step **1120**). The predicted election outcome of step **1120** differs from the predicted election outcome discussed with respect to FIG. **10**. The result of the predicted election outcome in FIG. **11** generally is not known in advance because the voter-marked ballots are generated by voters each potentially expressing intent differently or by different and imperfect marking styles on physical ballots and because the ballots are not machine-marked according to a predetermined voting pattern to desirably produce the expected or predicted result.

[0088] The process involves receiving an actual election outcome (step **1125**). The actual election outcome is typically provided by an election department administering an election. In some embodiments, the actual election outcome of step **1125** takes the form of a Statement of Votes Cast, as determined by the election department's vote tabulator (e.g. **865** in FIG. **8**). The actual election outcome of step **1125** is compared to the predicted election outcome of step **1120** in a comparison or determination process (step **1130**). If the comparison results in an acceptable match (e.g., both the actual election outcome and the predicted election outcome indicate a candidate received the same number of votes), the election can be certified or approved (step **1135**). If, on the other hand, the comparison of step **1130** results in a non-acceptable match, the election can be contested or further investigation into the discrepancy conducted (step **1140**). For example, if the predicted election outcome calculates 100 votes for Candidate A but the actual election outcome calculates 95 votes for Candidate A, the 5-vote discrepancy can be investigated (e.g., using the visualization tools of FIGS. **1-5**).

[0089] In some embodiments, the comparison of step **1130** is performed by comparing "match points" from the actual election outcome and the predicted election outcome. Discrepancies or mismatches in match points can give rise to discrepancies between the outcomes, and such discrepancies can be used to pinpoint ballots to be further investigated to determine voter intent or tabulator mis-reads.

[0090] The above-described techniques can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. The implementation can be as a computer program product, e.g., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. A computer program can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

[0091] Method steps can be performed by one or more programmable processors executing a computer program to perform functions of the technology by operating on input data and generating output. Method steps can also be performed by, and apparatus can be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit). Modules can refer to portions of the computer program and/or the processor/special circuitry that implements that functionality.

[0092] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor receives instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Data transmission and instructions can also occur over a communications network. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in special purpose logic circuitry.

[0093] The terms "module" and "function," as used herein, mean, but are not limited to, a software or hardware component which performs certain tasks. A module may advantageously be configured to reside on addressable storage medium and configured to execute on one or more processors. A module may be fully or partially implemented with a general purpose integrated circuit ("IC"), FPGA, or ASIC. Thus,

a module may include, by way of example, components, such as software components, object-oriented software components, class components and task components, processes, functions, attributes, procedures, subroutines, segments of program code, drivers, firmware, microcode, circuitry, data, databases, data structures, tables, arrays, and variables. The functionality provided for in the components and modules may be combined into fewer components and modules or further separated into additional components and modules. Additionally, the components and modules may advantageously be implemented on many different platforms, including computers, computer servers, data communications infrastructure equipment such as application-enabled switches or routers, or telecommunications infrastructure equipment, such as public or private telephone switches or private branch exchanges ("PBX"). In any of these cases, implementation may be achieved either by writing applications that are native to the chosen platform, or by interfacing the platform to one or more external application engines.

[0094] To provide for interaction with a user, the above described techniques can be implemented on a computer having a display device, e.g., a CRT (cathode ray tube) or LCD (liquid crystal display) monitor, for displaying information to the user and a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer (e.g., interact with a user interface element). Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input.

[0095] The above described techniques can be implemented in a distributed computing system that includes a back-end component, e.g., as a data server, and/or a middleware component, e.g., an application server, and/or a front-end component, e.g., a client computer having a graphical user interface and/or a Web browser through which a user can interact with an example implementation, or any combination of such back-end, middleware, or front-end components. The components of the system can be interconnected by any form or medium of digital data communications, e.g., a communications network. Examples of communications networks, also referred to as communications channels, include a local area network ("LAN") and a wide area network ("WAN"), e.g., the Internet, and include both wired and wireless networks. In some examples, communications networks can feature virtual networks or sub-networks such as a virtual local area network ("VLAN"). Unless clearly indicated otherwise, communications networks can also include all or a portion of the PSTN, for example, a portion owned by a specific carrier.

[0096] The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communications network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[0097] Various embodiments are depicted as in communication or connected by one or more communication paths. A communication path is not limited to a particular medium of transferring data. Information can be transmitted over a communication path using electrical, optical, acoustical, physical, thermal signals, or any combination thereof. A communication path can include multiple communication channels, for example, multiplexed channels of the same or varying capacities for data flow.

[0098] Multiple user inputs can be used to configure parameters of the depicted user interface features. Examples of such inputs include buttons, radio buttons, icons, check boxes, combo boxes, menus, text boxes, tooltips, toggle switches, buttons, scroll bars, toolbars, status bars, windows, or other suitable icons or widgets associated with user interfaces for allowing a user to communicate with and/or provide data to any of the modules or systems described herein.

[0099] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

[0100] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A method comprising:

receiving a computer-readable image of a ballot;

analyzing the image of the ballot with a computerized image analysis tool to generate a ballot definition file associated with the ballot; and

validating the ballot definition file.

2. The method of claim **1**, wherein validating the ballot definition file comprises:

generating a set of marked ballots based on a predetermined voting pattern and the ballot definition file;

processing the set of marked ballots with a vote tabulator and the ballot definition file to provide a simulated election outcome based on the set of marked ballots; and

comparing a predicted election outcome based on the predetermined voting pattern and the simulated election outcome.

3. The method of claim **2**, wherein generating the set of marked ballots comprises machine-marking the ballots based on the ballot-definition file.

4. The method of claim **2**, wherein generating the set of marked ballots comprises at least one of not voting, voting, overvoting, undervoting, or any combination thereof.

5. The method of claim **2**, further comprising generating a first statement of votes cast associated with the predicted election outcome and a second statement of votes cast associated with the simulated election outcome.

6. The method of claim **5**, wherein comparing the predicted election outcome with the simulated election outcome comprises comparing the first and second statements of votes cast.

7. The method of claim **6**, wherein comparing the first and second statements of votes cast comprises comparing a set of match points from the predicted election and a set of match points from the simulated election.

8. The method of claim **1**, further comprising:

processing a set of voter-marked ballots with a first vote tabulator and the ballot definition file to determine a predicted election outcome;

receiving an actual election outcome determined by a second vote tabulator processing the set of voter-marked ballots; and

comparing the predicted election outcome and the actual election outcome.

9. The method of claim **8**, wherein comparing the predicted election outcome with the actual election outcome comprises comparing a first statement of votes cast being associated with the predicted election outcome and generated by the first vote tabulator and a second statement of votes cast being associated with the actual election outcome and generated by the second vote tabulator.

10. The method of claim **9**, wherein comparing the first and second statements of votes cast comprises comparing a set of match points from the predicted election and a set of match points from the actual election.

11. The method of claim **1**, wherein the generated ballot definition file is based on the ballot style of the received ballot.

12. The method of claim **1**, wherein analyzing the image of the ballot comprises:

determining a location of a contest zone, a vote target, or both;

determining election information from the image, the election information comprising at least one of a precinct, a district, a jurisdiction name, an election date, or any combination thereof; and

associating at least one of a race name, a choice name, a voting rule, or any combination thereof with the contest zone, vote target, or both.

13. The method of claim **12**, further comprising associating a ballot-style identifier and a ballot-side with the analyzed ballot.

14. The method of claim **1**, wherein analyzing the image of the ballot comprises associating a location of a vote target with a timing mark on the ballot.

15. The method of claim **1**, wherein the set of marked ballots comprises voter-marked ballots.

16. A computer program product, tangibly embodied in a non-transitory computer-readable storage medium, containing instructions operable to cause data processing apparatus to:

receive a computer-readable image of a ballot;

analyze the image of the ballot with a computerized image analysis tool to generate a ballot-definition file associated with the ballot; and

validate the ballot definition file.

17. The computer program product of claim **16**, wherein the instructions operable to validate the ballot definition file further comprise instructions operable to cause data processing apparatus to:

generate a set of marked ballots based on a predetermined voting pattern and the ballot-definition file;

process the set of marked ballots with a vote tabulator and the ballot definition file to provide a simulated election outcome based on the set of marked ballots; and

compare a predicted election outcome based on the predetermined voting pattern and the simulated election outcome.

18. The computer program product of claim **16**, further comprising instructions operable to cause data processing apparatus to:

process a set of voter-marked ballots with a first vote tabulator and the ballot definition file to determine a predicted election outcome;

receive an actual election outcome determined by a second vote tabulator processing the set of voter-marked ballots; and

compare the predicted election outcome and the actual election outcome.

19. A system for assessing an election result, the system comprising:

an input module to receive a computer-readable image of a ballot;

an image analysis module configured to analyze the image of the ballot;

a file-generation module in communication with the image analysis module to generate a ballot-definition file based on an output of the image analysis module; and

a file validation module to validate the ballot definition file.

20. The system of claim **19**, further comprising

an interface to a vote tabulator for communicating the generated ballot-definition file to the vote tabulator to facilitate processing a set of machine-marked ballots, voter-marked ballots, or both.

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