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(54) **EFFICIENT PROCESSING OF TRIE DATA STRUCTURES TO SUPPORT CUSTOMER JOURNEY VISUALIZATIONS**

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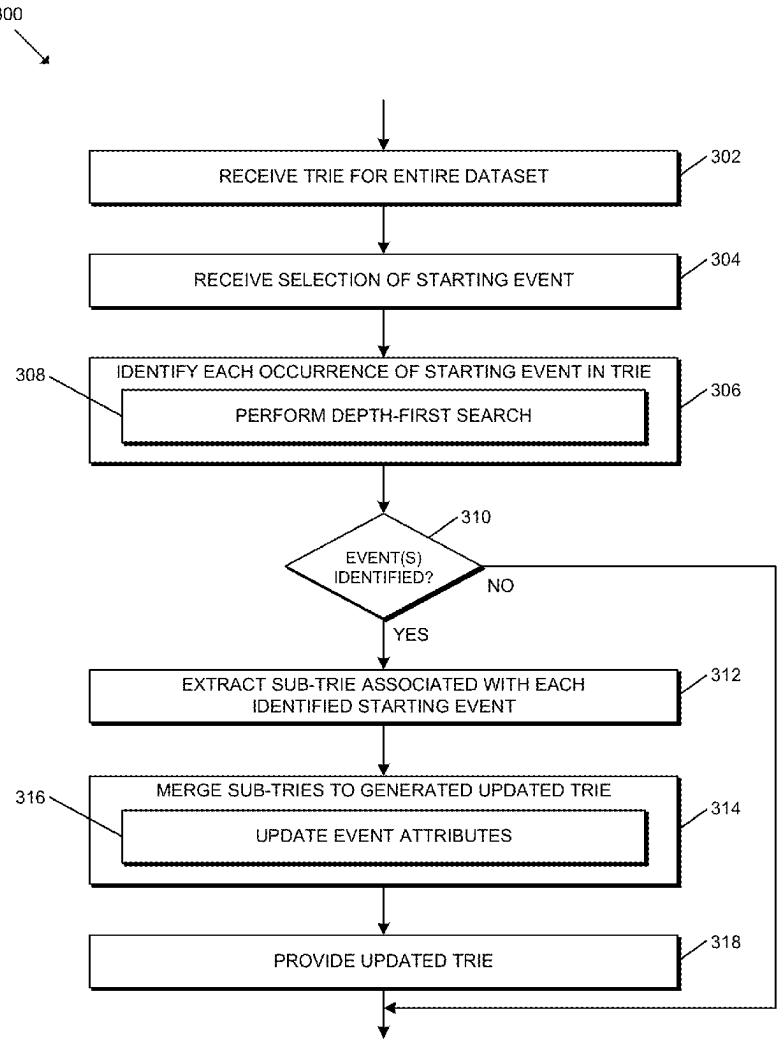
(52) **U.S. Cl.**
CPC ..... ***G06F 16/211*** (2019.01)

(57) **ABSTRACT**

A method for providing efficient trie data structure processing according to an embodiment includes splitting, based on organization identifiers and sequence identifiers, a data frame indicative of a set of events associated with customer interactions with automated agents of a contact center to produce a set of multiple partitions, and producing a set of multiple trie data structures, including generating a trie data structure for each partition. Each trie data structure represents aggregate counts of a corresponding subset of event sequences associated with a corresponding organization. The method also includes merging multiple trie data structures of the set of trie data structures to produce a combined organization trie data structure and storing the combined organization trie data structure to enable generation of a visualization of the combined organization trie data structure.



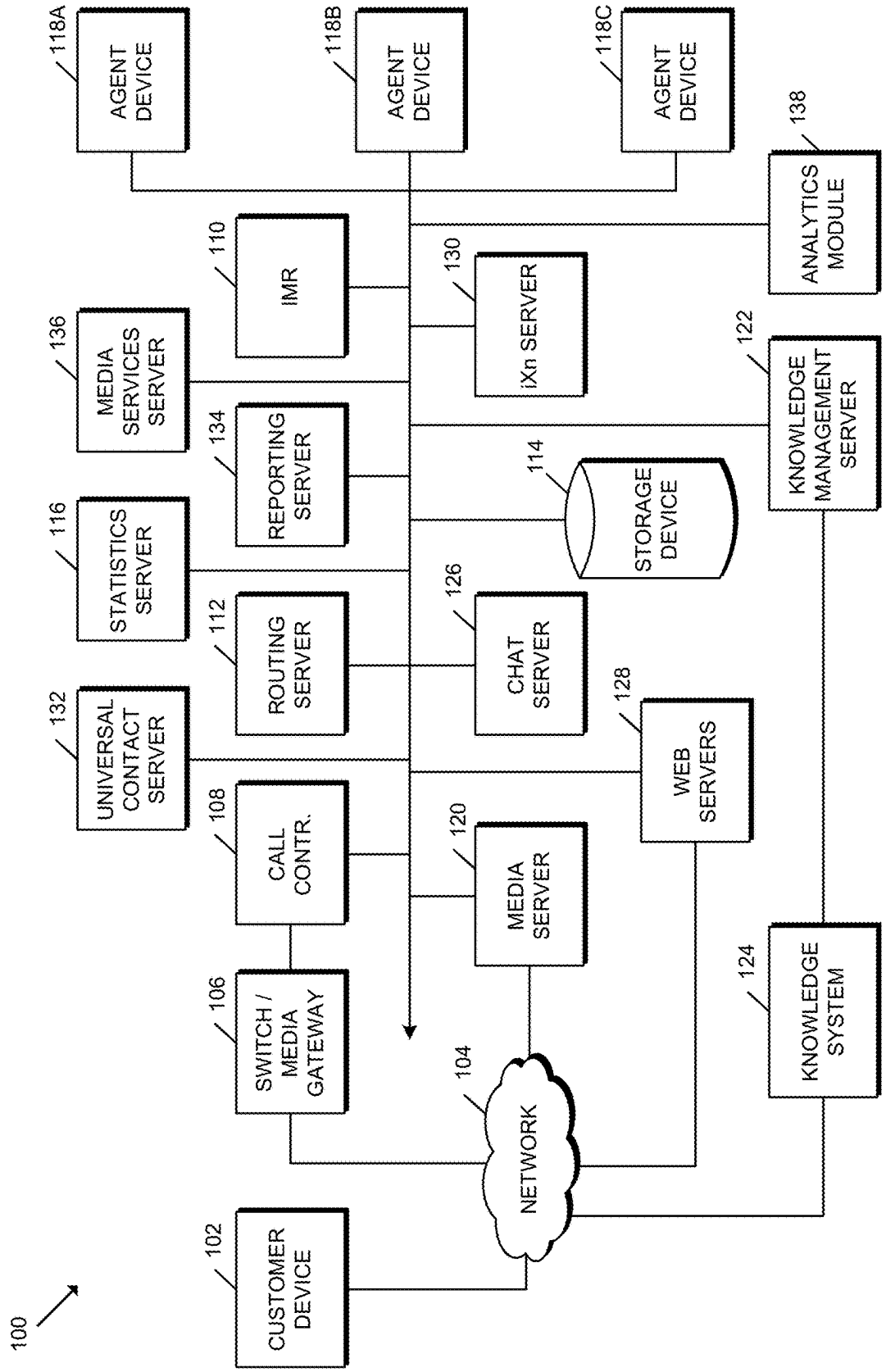

100
CUSTOMER DEVICE
102
NETWORK
104
SWITCH / MEDIA GATEWAY
106
CALL CONTR.
108
ROUTING SERVER
112
IMR
110
STATISTICS SERVER
116
REPORTING SERVER
134
MEDIA SERVICES SERVER
136
UNIVERSAL CONTACT SERVER
132
MEDIA SERVER
120
CHAT SERVER
126
WEB SERVERS
128
iXn SERVER
130
STORAGE DEVICE
114
KNOWLEDGE SYSTEM
124
KNOWLEDGE MANAGEMENT SERVER
122
ANALYTICS MODULE
138
AGENT DEVICE
118A
AGENT DEVICE
118B
AGENT DEVICE
118C

FIG. 1

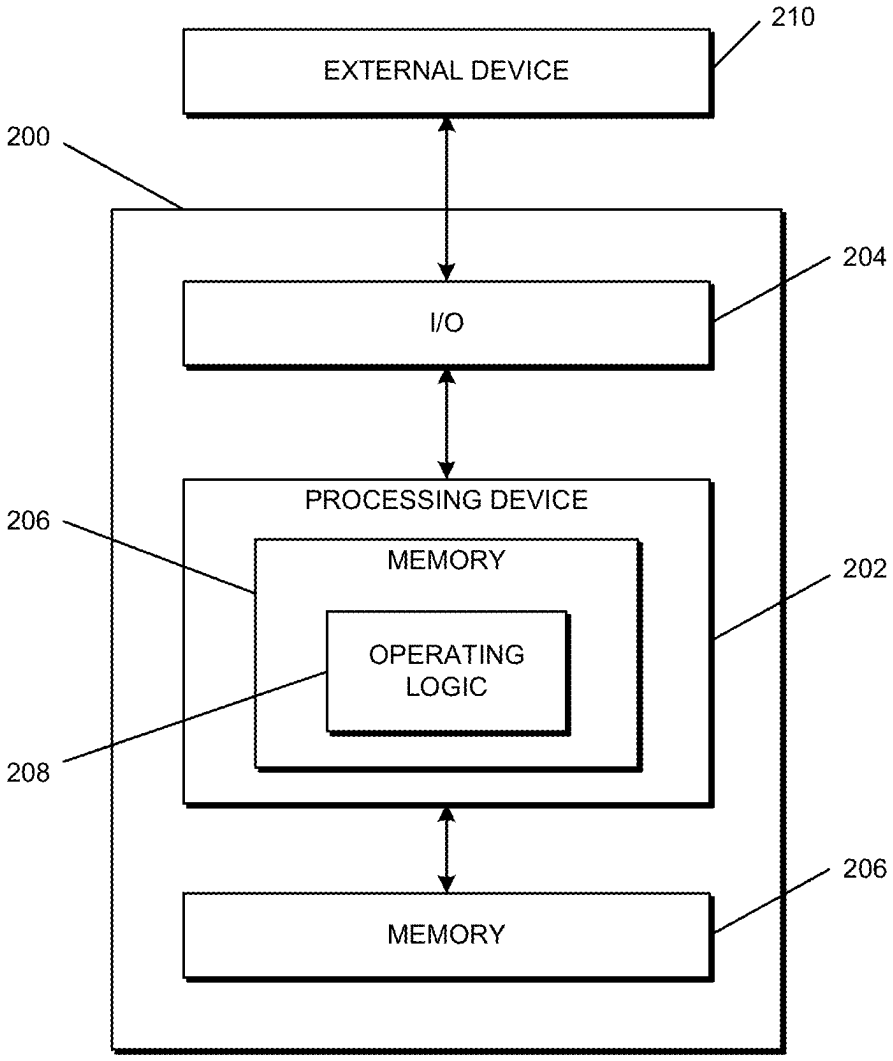

210
EXTERNAL DEVICE
200
204
I/O
PROCESSING DEVICE
206
MEMORY
202
OPERATING LOGIC
208
206
MEMORY

FIG. 2

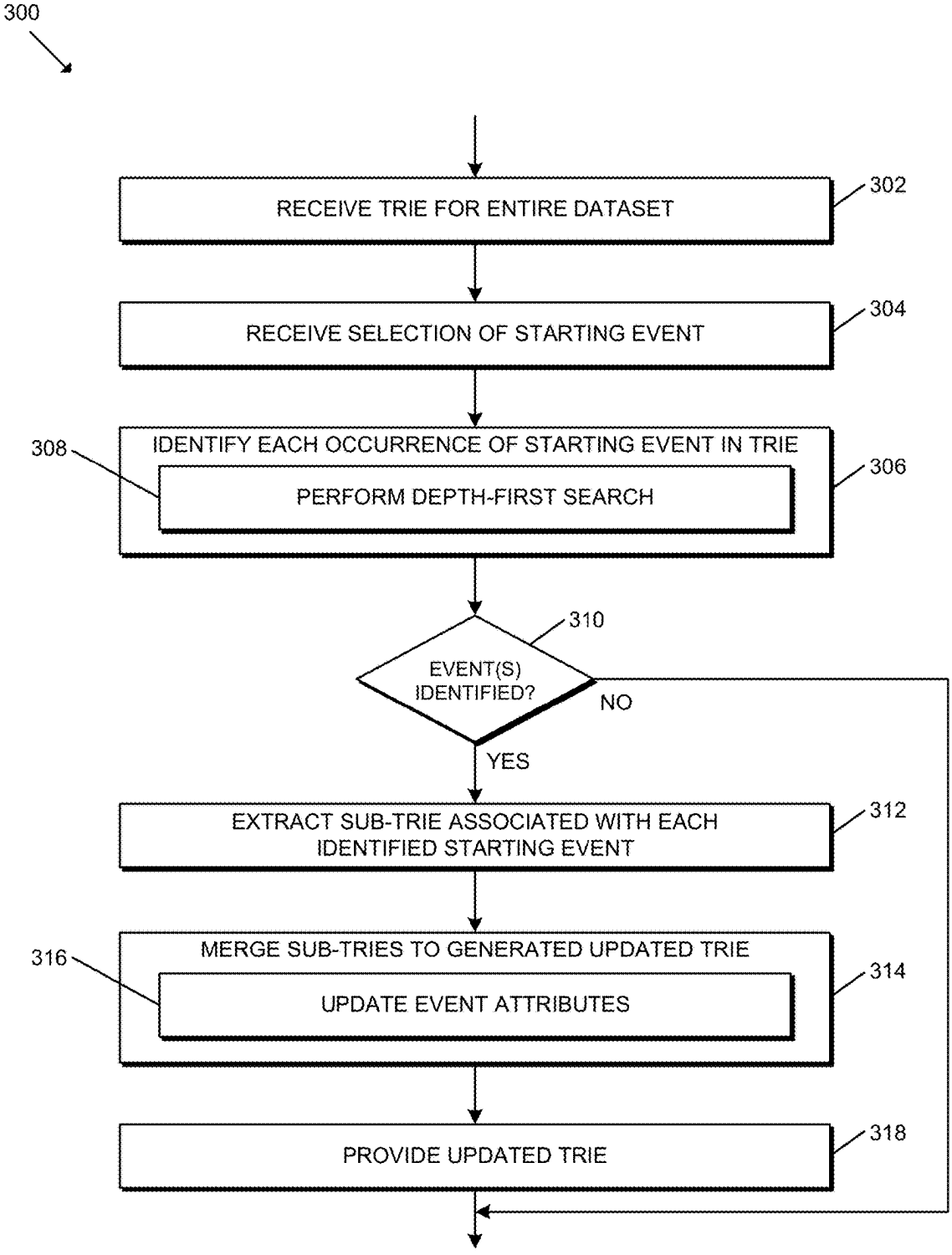

300
RECEIVE TRIE FOR ENTIRE DATASET
302
RECEIVE SELECTION OF STARTING EVENT
304
IDENTIFY EACH OCCURRENCE OF STARTING EVENT IN TRIE
PERFORM DEPTH-FIRST SEARCH
308
306
310
EVENT(S) IDENTIFIED?
NO
YES
EXTRACT SUB-TRIE ASSOCIATED WITH EACH IDENTIFIED STARTING EVENT
312
MERGE SUB-TRIES TO GENERATED UPDATED TRIE
UPDATE EVENT ATTRIBUTES
316
314
PROVIDE UPDATED TRIE
318

FIG. 3

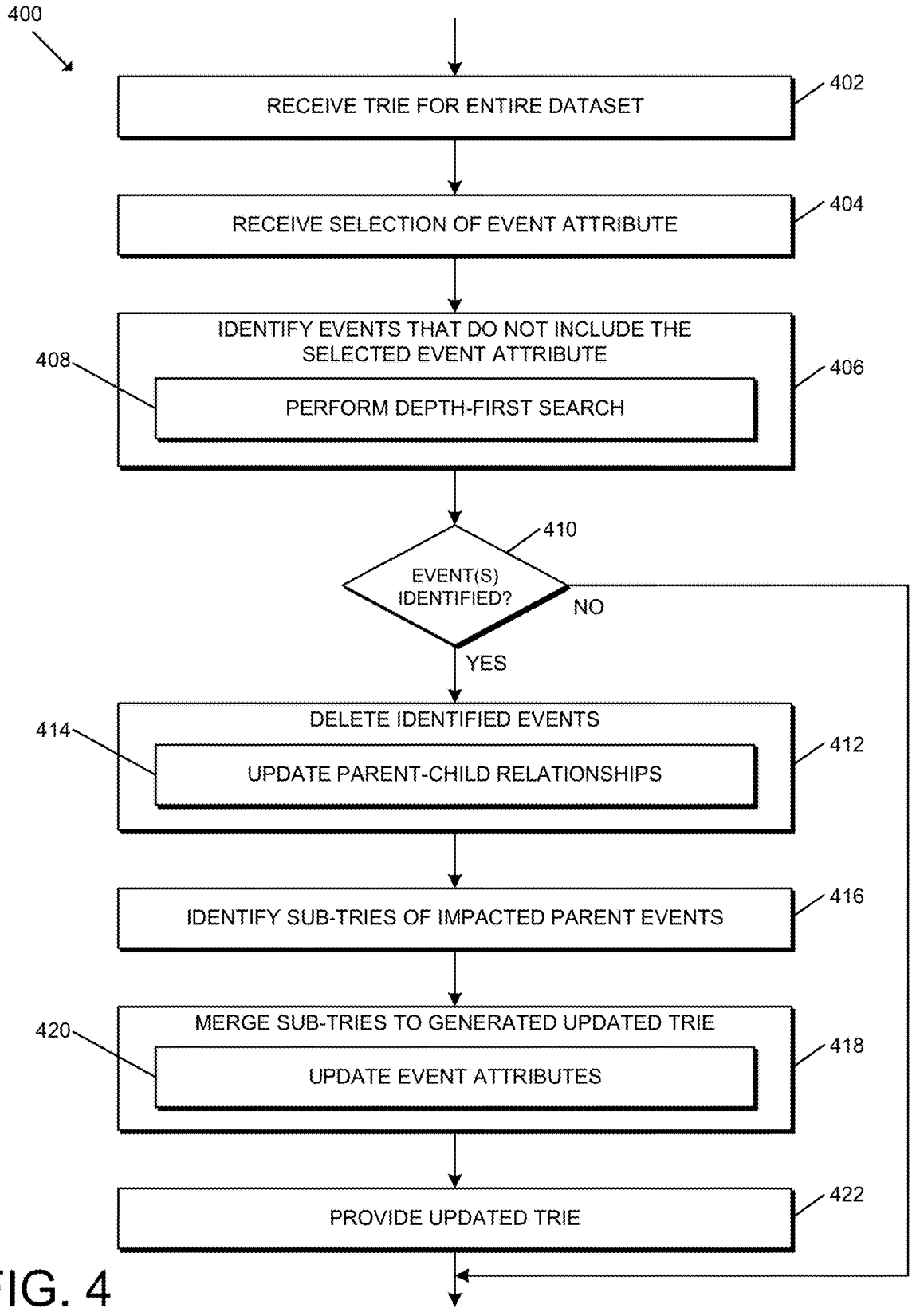

400
RECEIVE TRIE FOR ENTIRE DATASET
402
RECEIVE SELECTION OF EVENT ATTRIBUTE
404
IDENTIFY EVENTS THAT DO NOT INCLUDE THE SELECTED EVENT ATTRIBUTE
408
PERFORM DEPTH-FIRST SEARCH
406
410
EVENT(S) IDENTIFIED?
NO
YES
DELETE IDENTIFIED EVENTS
414
UPDATE PARENT-CHILD RELATIONSHIPS
412
IDENTIFY SUB-TRIES OF IMPACTED PARENT EVENTS
416
MERGE SUB-TRIES TO GENERATED UPDATED TRIE
420
UPDATE EVENT ATTRIBUTES
418
PROVIDE UPDATED TRIE
422

FIG. 4

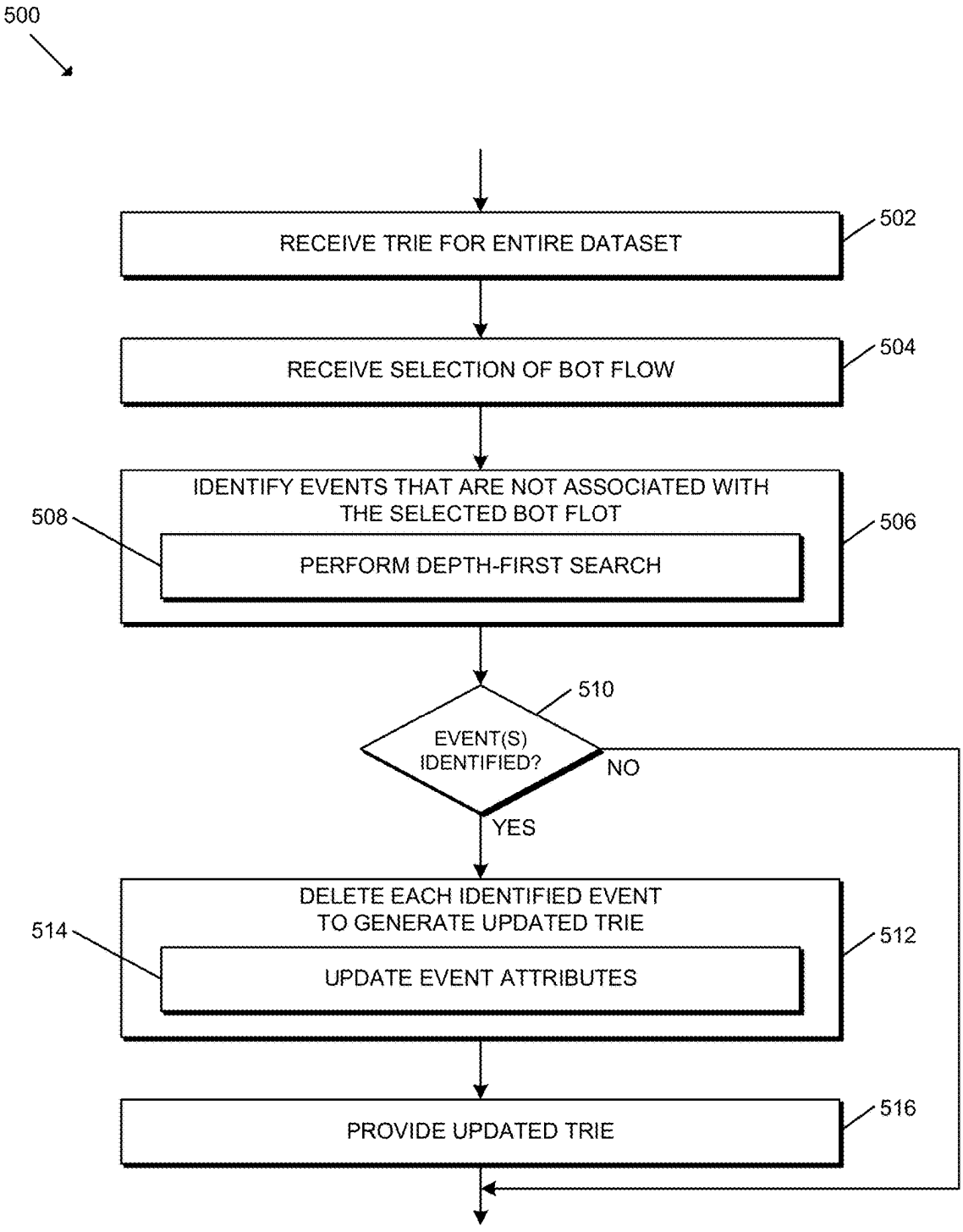

500
RECEIVE TRIE FOR ENTIRE DATASET
502
RECEIVE SELECTION OF BOT FLOW
504
IDENTIFY EVENTS THAT ARE NOT ASSOCIATED WITH THE SELECTED BOT FLOT
508
PERFORM DEPTH-FIRST SEARCH
506
510
EVENT(S) IDENTIFIED?
NO
YES
DELETE EACH IDENTIFIED EVENT TO GENERATE UPDATED TRIE
514
UPDATE EVENT ATTRIBUTES
512
PROVIDE UPDATED TRIE
516

FIG. 5

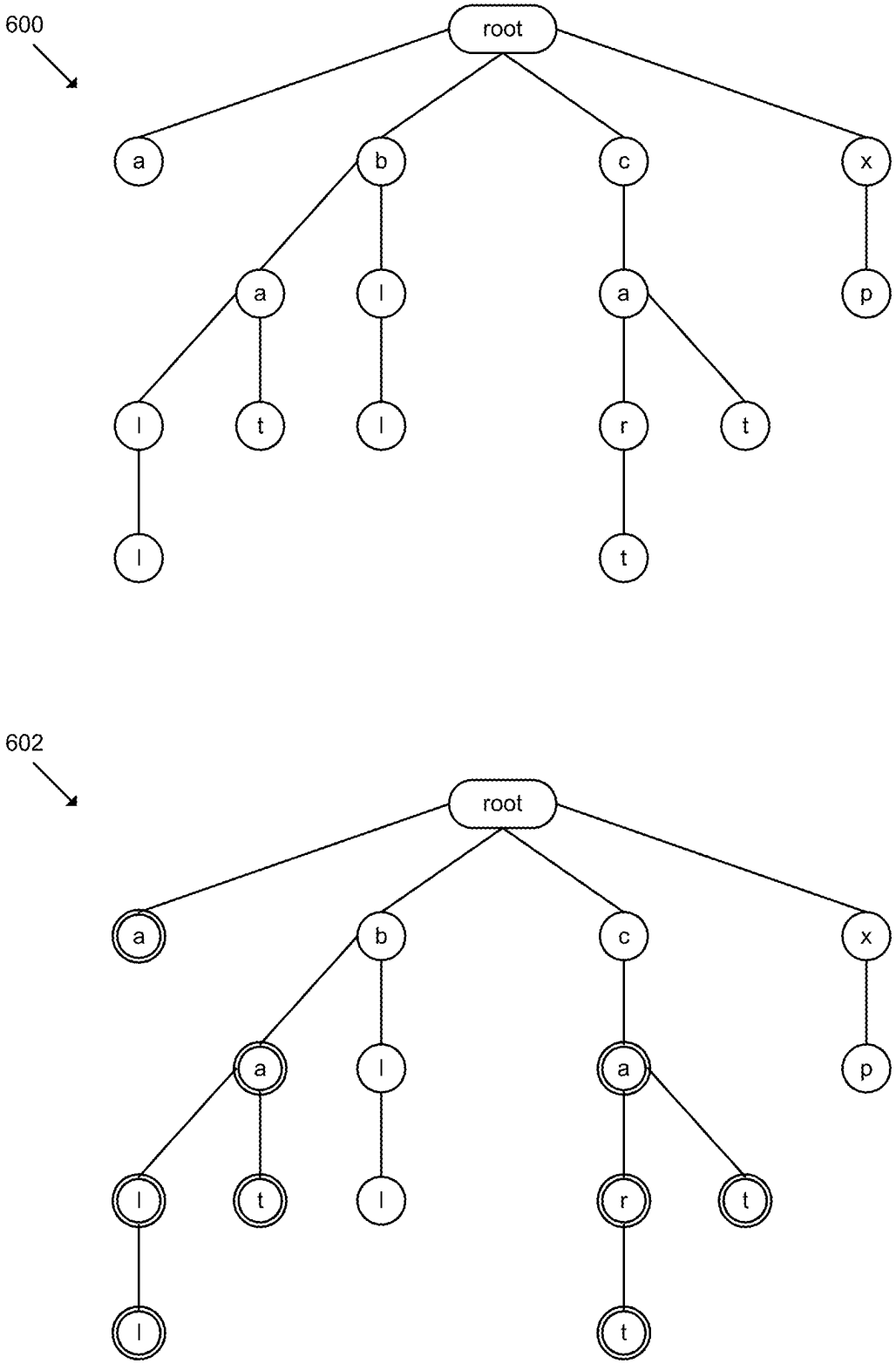



FIG. 6

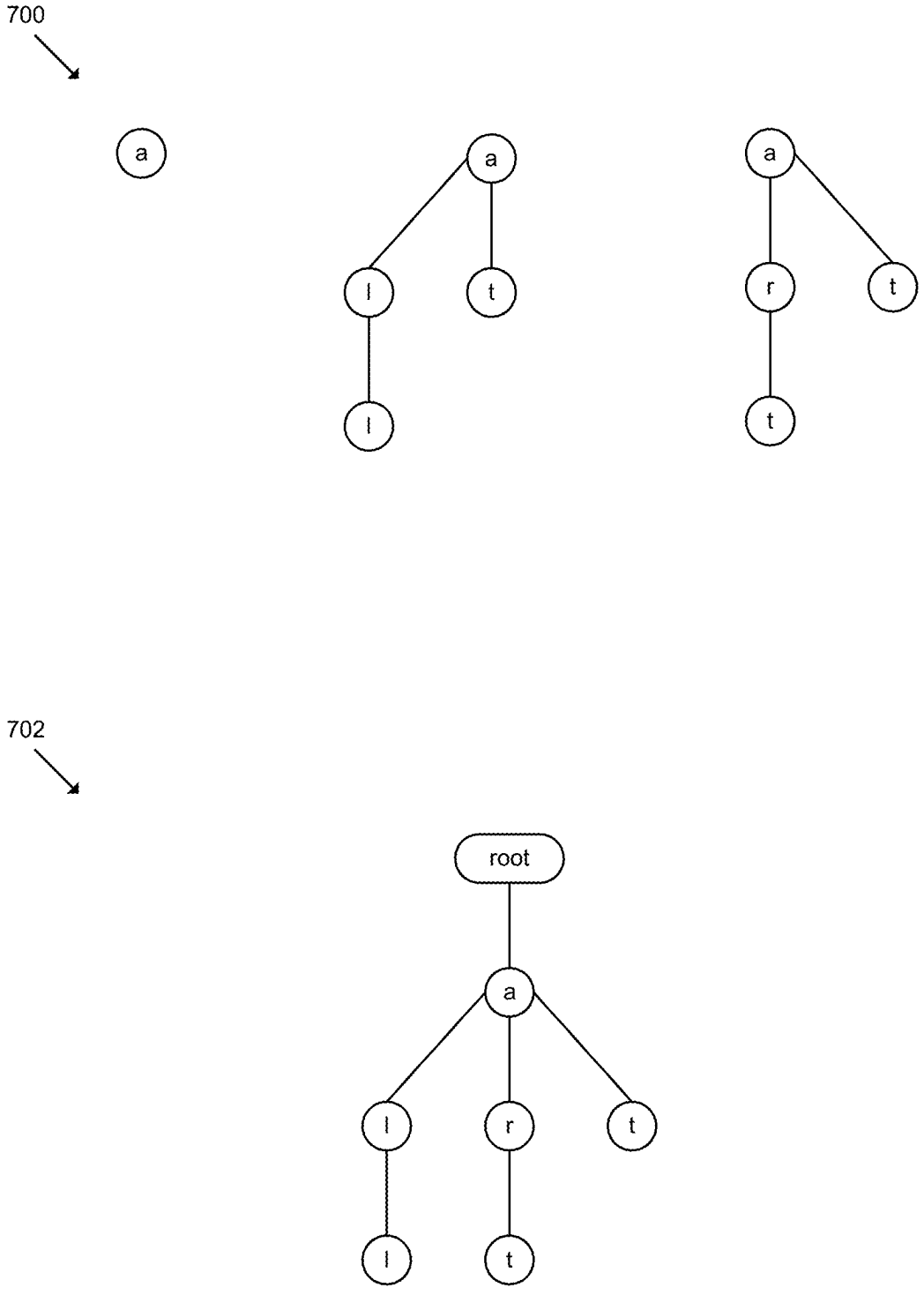



FIG. 7

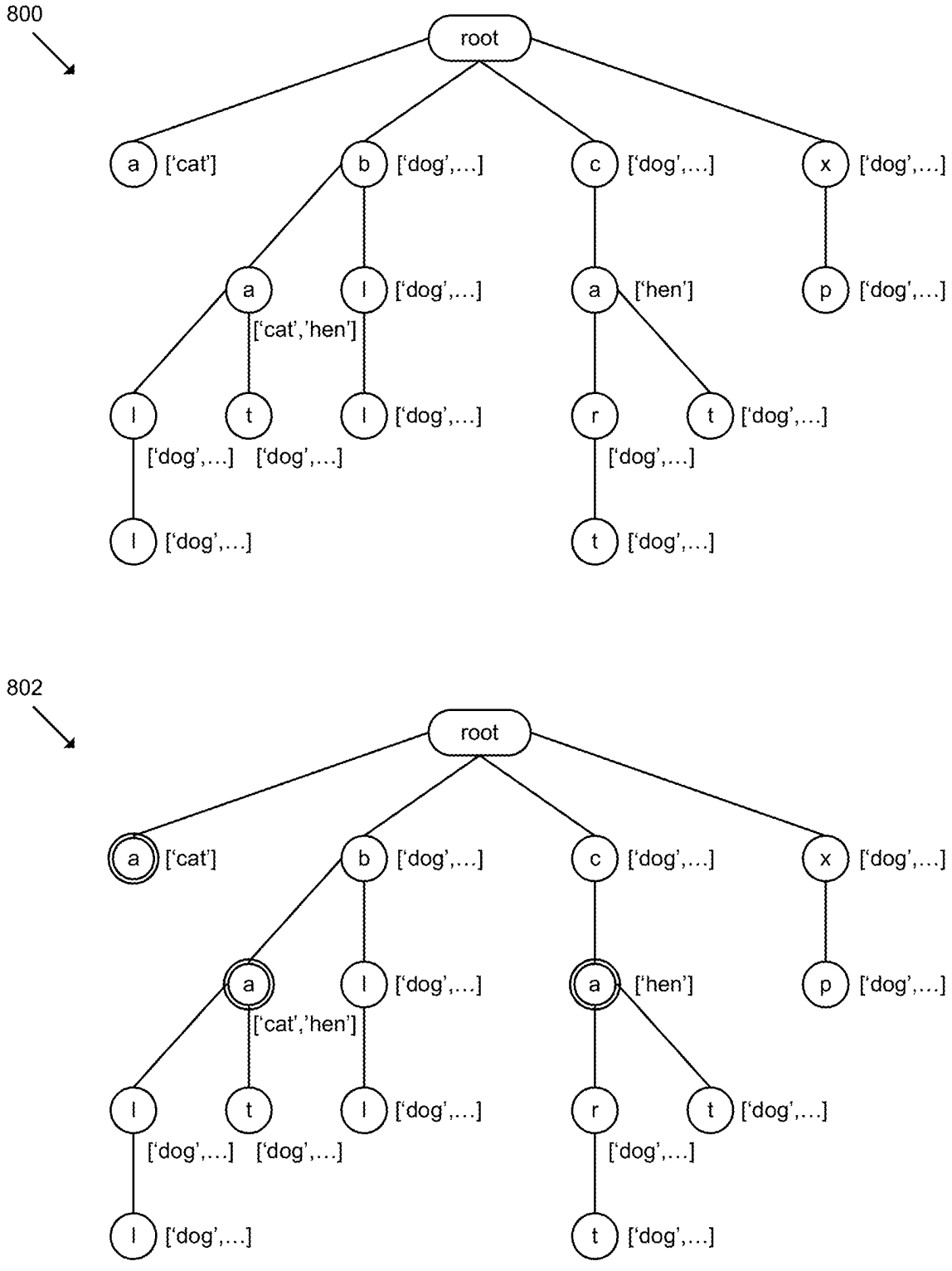

800
root
a ['cat']
b ['dog',...]
c ['dog',...]
x ['dog',...]
a
l ['dog',...]
a ['hen']
p ['dog',...]
['cat','hen']
l
t
l ['dog',...]
r
t ['dog',...]
['dog',...]
['dog',...]
['dog',...]
l ['dog',...]
t ['dog',...]
802
root
a ['cat']
b ['dog',...]
c ['dog',...]
x ['dog',...]
a
l ['dog',...]
a ['hen']
p ['dog',...]
['cat','hen']
l
t
l ['dog',...]
r
t ['dog',...]
['dog',...]
['dog',...]
['dog',...]
l ['dog',...]
t ['dog',...]

FIG. 8

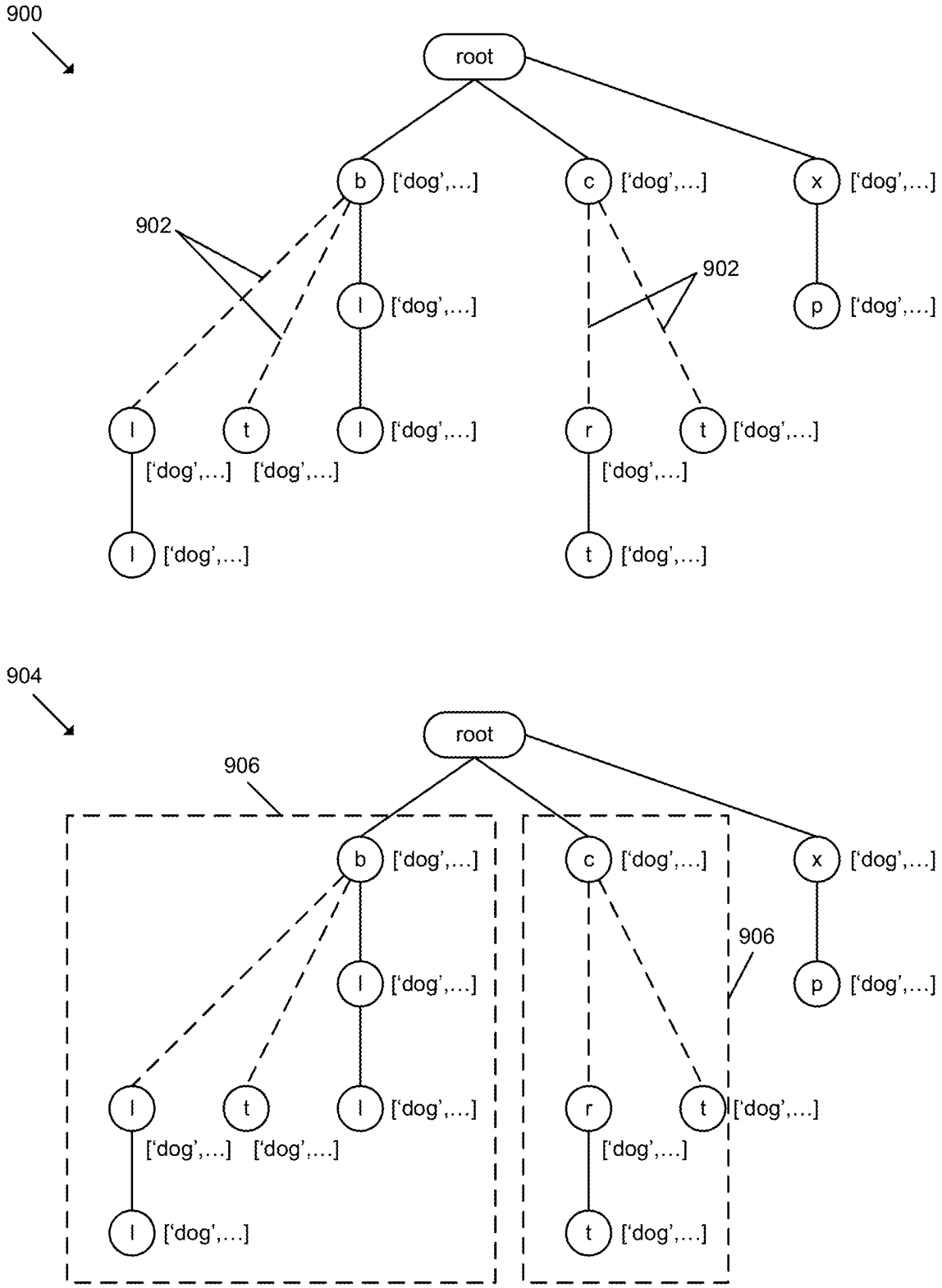

900
root
b ['dog',...]
c ['dog',...]
x ['dog',...]
902
902
l ['dog',...]
p ['dog',...]
l
t
l ['dog',...]
r
t ['dog',...]
['dog',...]
['dog',...]
['dog',...]
l ['dog',...]
t ['dog',...]
904
root
906
b ['dog',...]
c ['dog',...]
x ['dog',...]
906
l ['dog',...]
p ['dog',...]
l
t
l ['dog',...]
r
t ['dog',...]
['dog',...]
['dog',...]
['dog',...]
l ['dog',...]
t ['dog',...]

FIG. 9

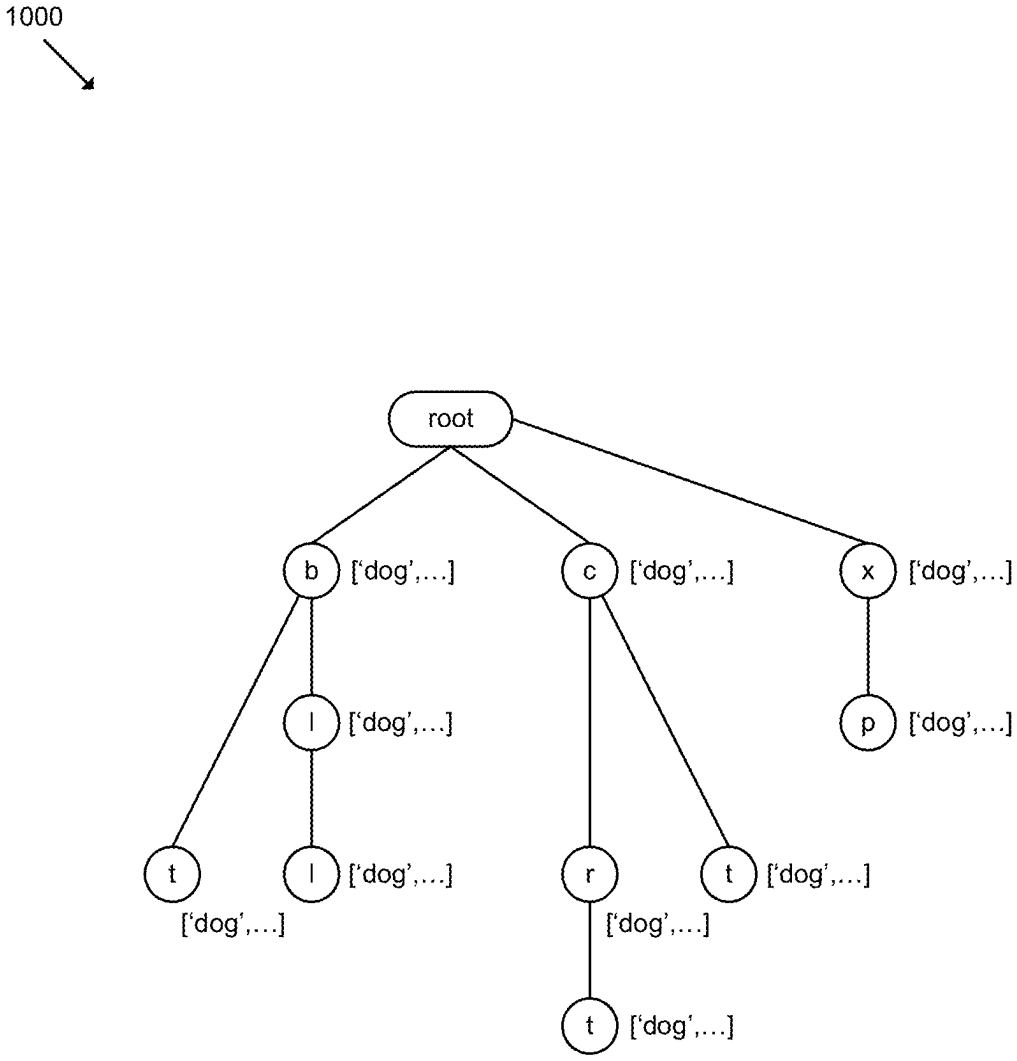



FIG. 10

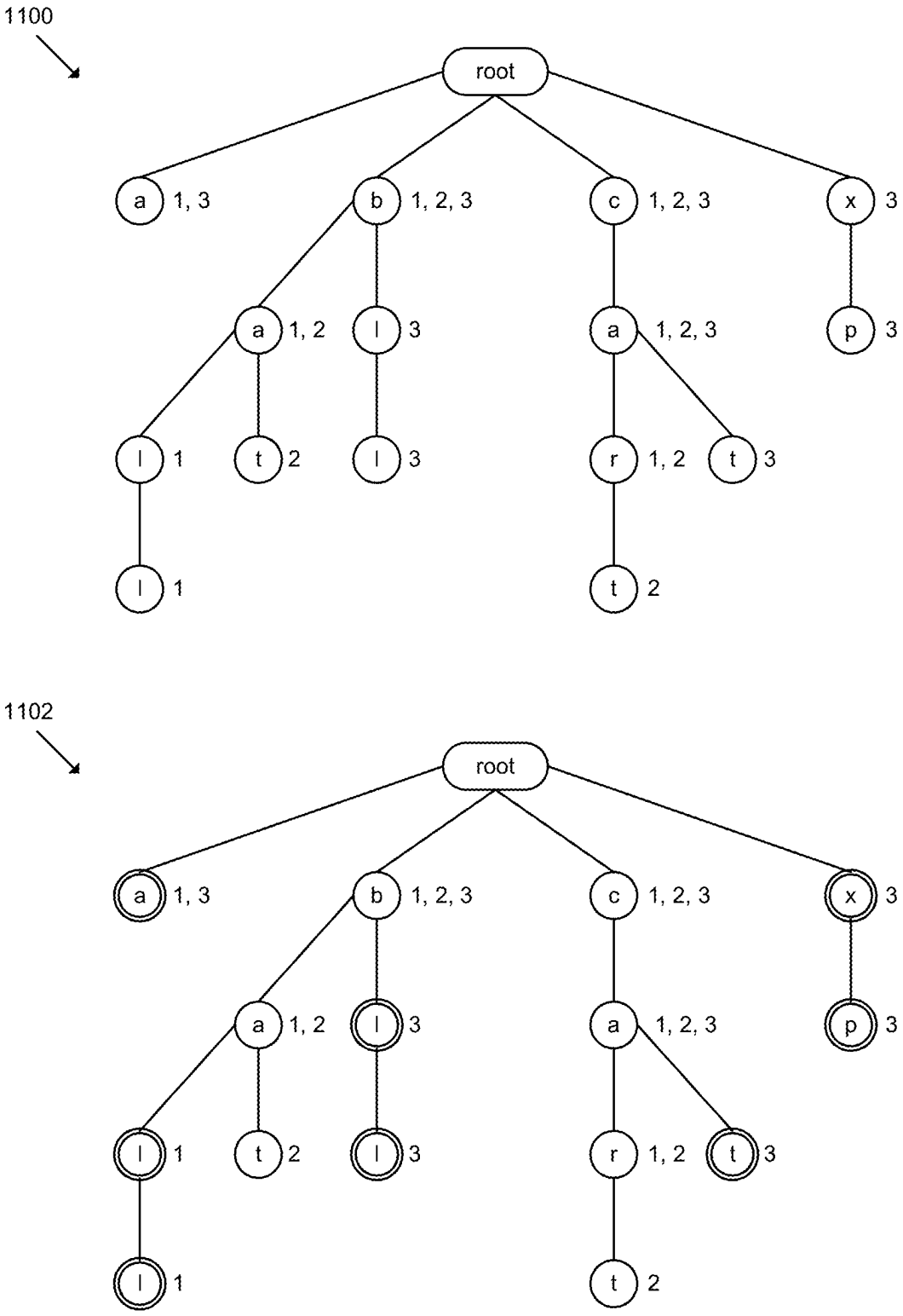
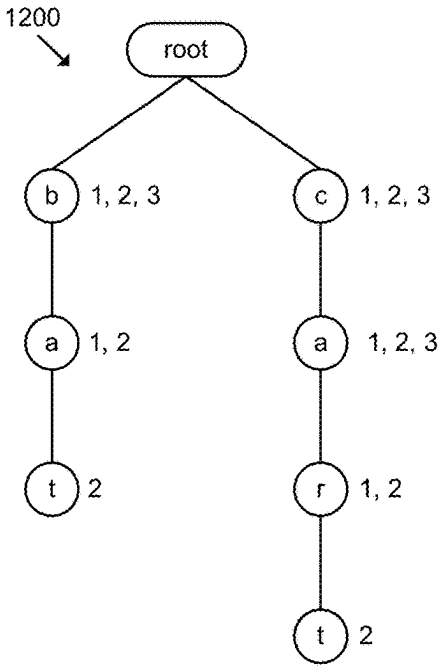
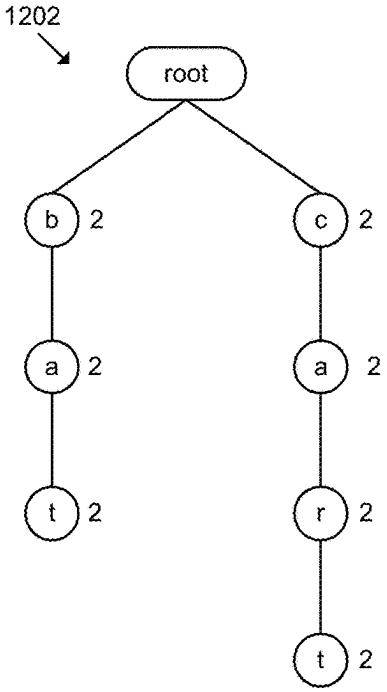

1100
root
a 1, 3
b 1, 2, 3
c 1, 2, 3
x 3
a 1, 2
l 3
a 1, 2, 3
p 3
l 1
t 2
l 3
r 1, 2
t 3
l 1
t 2
1102
root
a 1, 3
b 1, 2, 3
c 1, 2, 3
x 3
a 1, 2
l 3
a 1, 2, 3
p 3
l 1
t 2
l 3
r 1, 2
t 3
l 1
t 2

FIG. 11




```
Node Attributes:
{
        flow_ids: [flow_1, flow_2, flow_3]

        event_name: c

        flow_1:
                (count_1, ['attribute_1'])

        flow_2:
                (count_2, ['attribute_2'])

        flow_3:
                (count_3, ['attribute_3'])

        aggregate:
                (count_1 + count_2 + count_3, ['attribute_1',
                'attribute_2', 'attribute_3'])
}
```




```
Node Attributes:
{
        flow_ids: [flow_2]

        event_name: c

        flow_2:
                (count_2, ['attribute_2'])

        aggregate:
                (count_2, ['attribute_2'])
}
```

FIG. 12

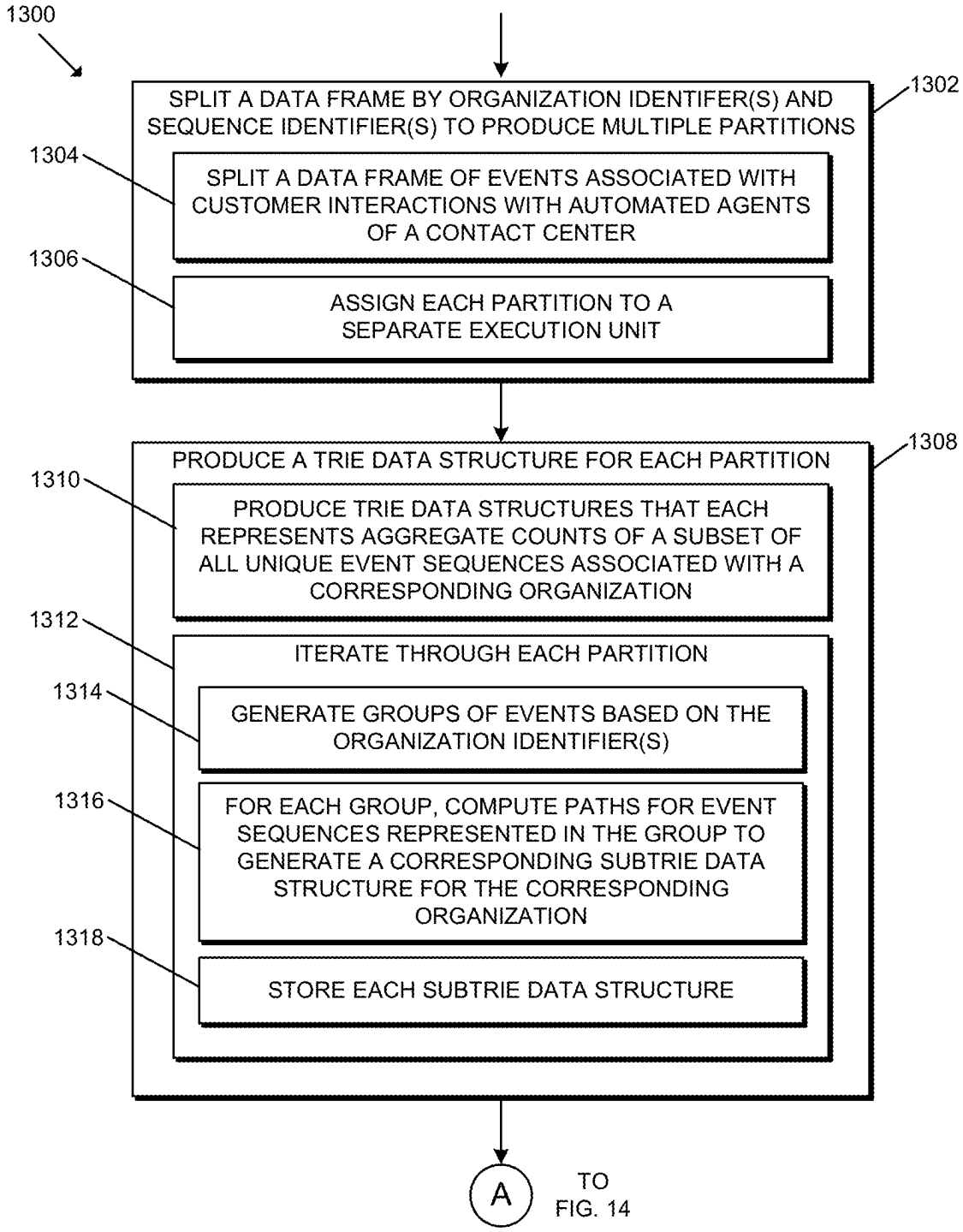

1300
SPLIT A DATA FRAME BY ORGANIZATION IDENTIFER(S) AND SEQUENCE IDENTIFIER(S) TO PRODUCE MULTIPLE PARTITIONS
1302
1304
SPLIT A DATA FRAME OF EVENTS ASSOCIATED WITH CUSTOMER INTERACTIONS WITH AUTOMATED AGENTS OF A CONTACT CENTER
1306
ASSIGN EACH PARTITION TO A SEPARATE EXECUTION UNIT
PRODUCE A TRIE DATA STRUCTURE FOR EACH PARTITION
1308
1310
PRODUCE TRIE DATA STRUCTURES THAT EACH REPRESENTS AGGREGATE COUNTS OF A SUBSET OF ALL UNIQUE EVENT SEQUENCES ASSOCIATED WITH A CORRESPONDING ORGANIZATION
1312
ITERATE THROUGH EACH PARTITION
1314
GENERATE GROUPS OF EVENTS BASED ON THE ORGANIZATION IDENTIFIER(S)
1316
FOR EACH GROUP, COMPUTE PATHS FOR EVENT SEQUENCES REPRESENTED IN THE GROUP TO GENERATE A CORRESPONDING SUBTRIE DATA STRUCTURE FOR THE CORRESPONDING ORGANIZATION
1318
STORE EACH SUBTRIE DATA STRUCTURE
A
TO FIG. 14

FIG. 13

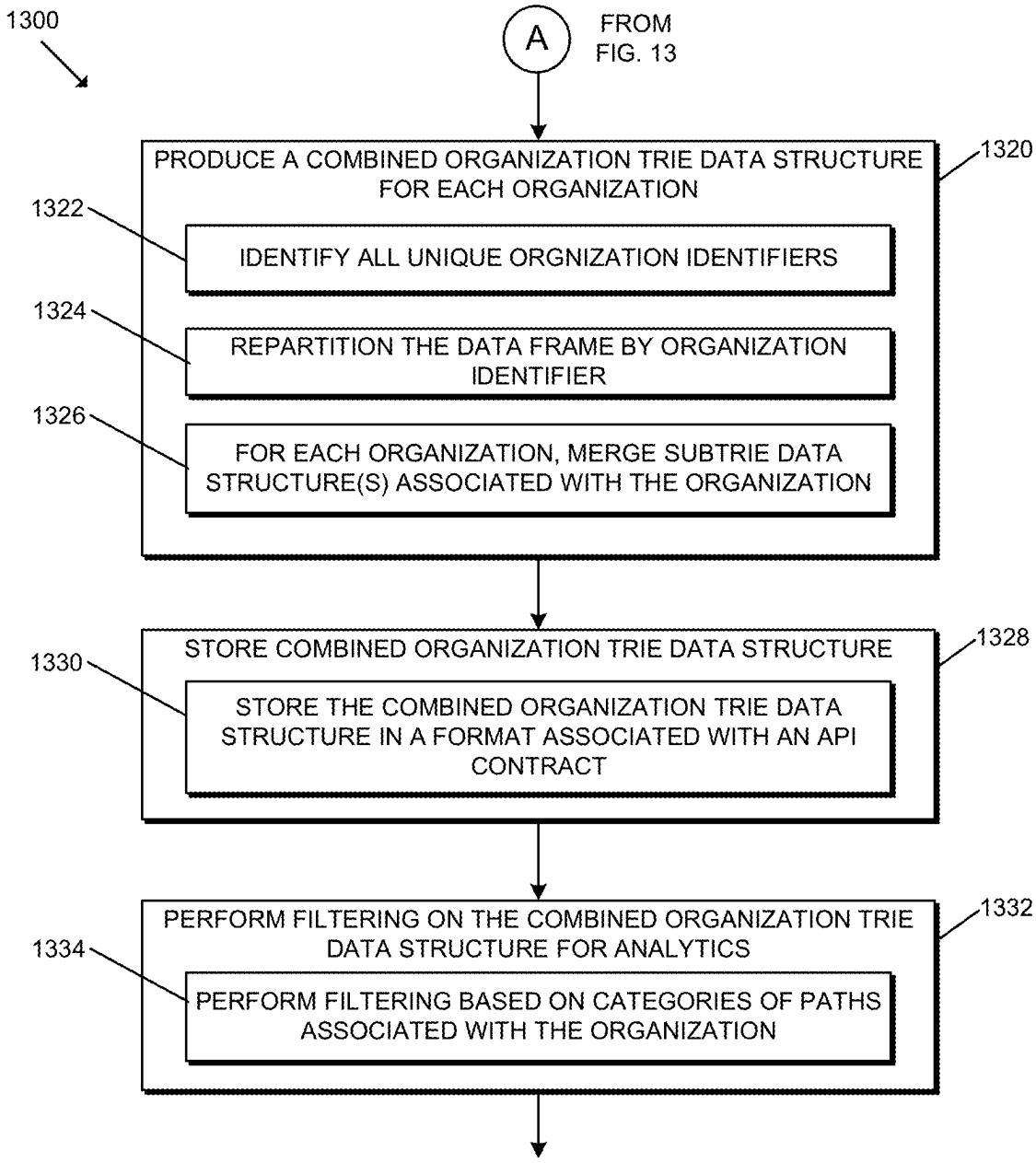

1300
A
FROM FIG. 13
PRODUCE A COMBINED ORGANIZATION TRIE DATA STRUCTURE FOR EACH ORGANIZATION
1320
1322
IDENTIFY ALL UNIQUE ORGNIZATION IDENTIFIERS
1324
REPARTITION THE DATA FRAME BY ORGANIZATION IDENTIFIER
1326
FOR EACH ORGANIZATION, MERGE SUBTRIE DATA STRUCTURE(S) ASSOCIATED WITH THE ORGANIZATION
STORE COMBINED ORGANIZATION TRIE DATA STRUCTURE
1328
1330
STORE THE COMBINED ORGANIZATION TRIE DATA STRUCTURE IN A FORMAT ASSOCIATED WITH AN API CONTRACT
PERFORM FILTERING ON THE COMBINED ORGANIZATION TRIE DATA STRUCTURE FOR ANALYTICS
1332
1334
PERFORM FILTERING BASED ON CATEGORIES OF PATHS ASSOCIATED WITH THE ORGANIZATION

FIG. 14

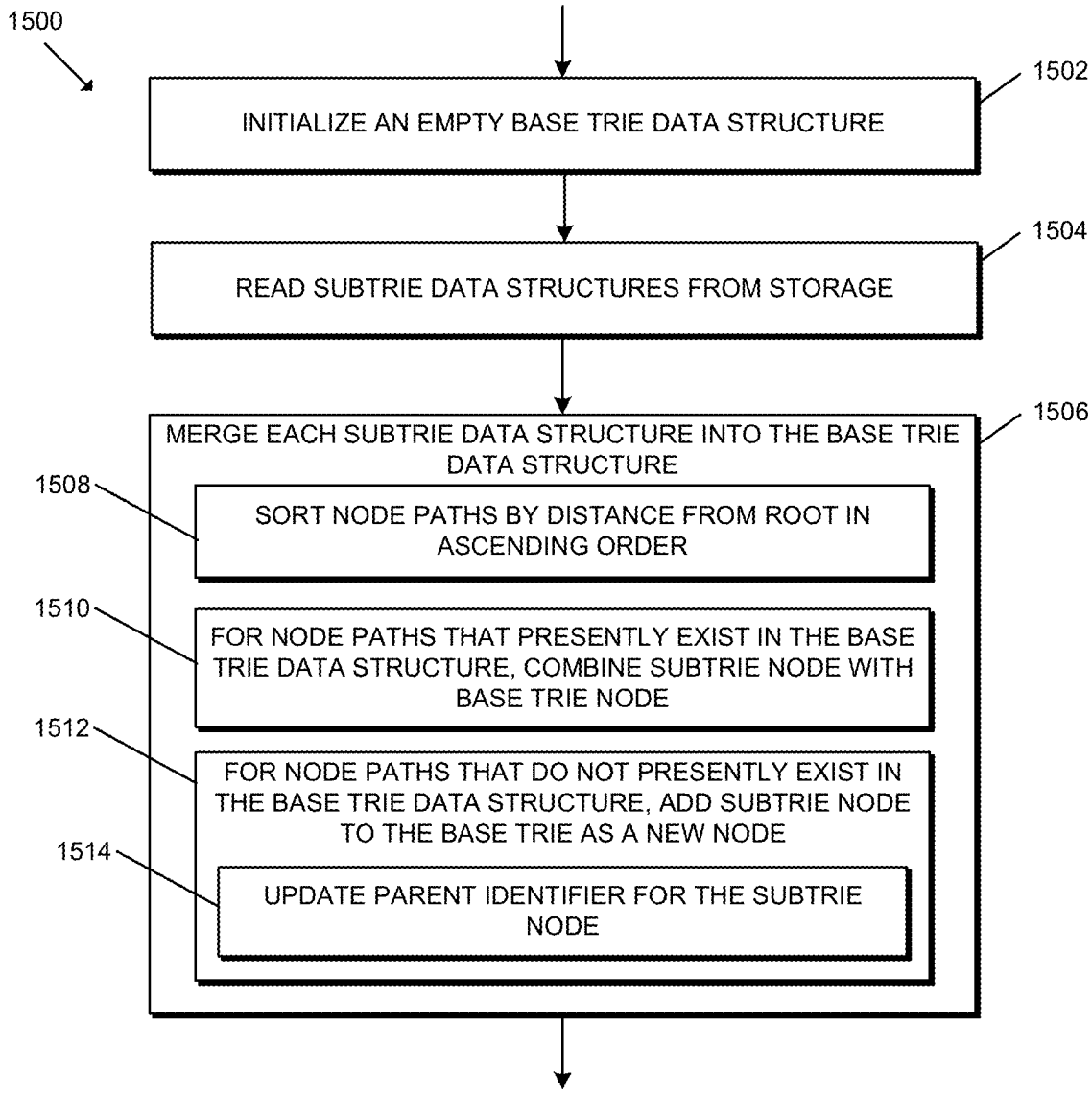

1500
INITIALIZE AN EMPTY BASE TRIE DATA STRUCTURE
1502
READ SUBTRIE DATA STRUCTURES FROM STORAGE
1504
MERGE EACH SUBTRIE DATA STRUCTURE INTO THE BASE TRIE DATA STRUCTURE
1506
1508
SORT NODE PATHS BY DISTANCE FROM ROOT IN ASCENDING ORDER
1510
FOR NODE PATHS THAT PRESENTLY EXIST IN THE BASE TRIE DATA STRUCTURE, COMBINE SUBTRIE NODE WITH BASE TRIE NODE
1512
FOR NODE PATHS THAT DO NOT PRESENTLY EXIST IN THE BASE TRIE DATA STRUCTURE, ADD SUBTRIE NODE TO THE BASE TRIE AS A NEW NODE
1514
UPDATE PARENT IDENTIFIER FOR THE SUBTRIE NODE

FIG. 15

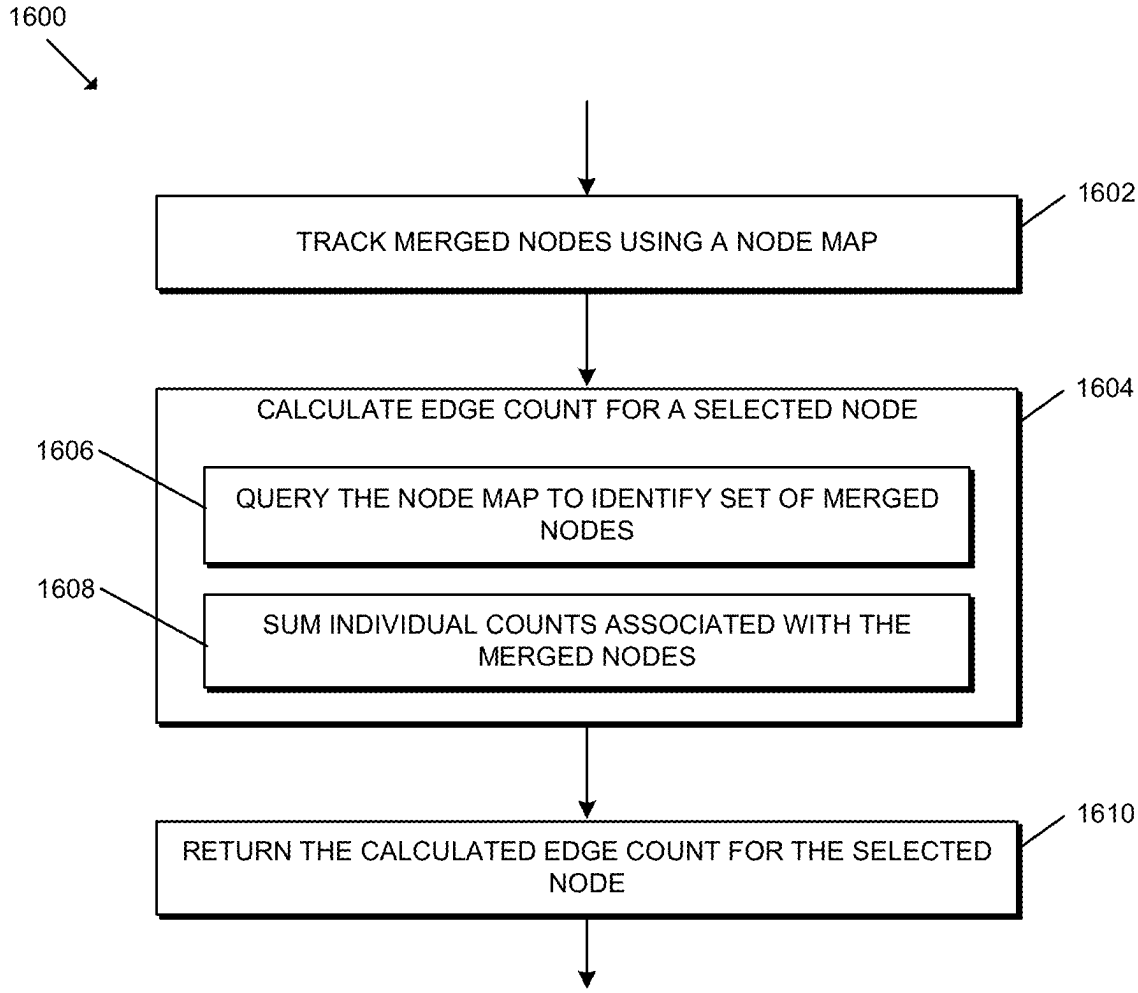

1600
TRACK MERGED NODES USING A NODE MAP
1602
CALCULATE EDGE COUNT FOR A SELECTED NODE
1604
1606
QUERY THE NODE MAP TO IDENTIFY SET OF MERGED NODES
1608
SUM INDIVIDUAL COUNTS ASSOCIATED WITH THE MERGED NODES
RETURN THE CALCULATED EDGE COUNT FOR THE SELECTED NODE
1610

FIG. 16

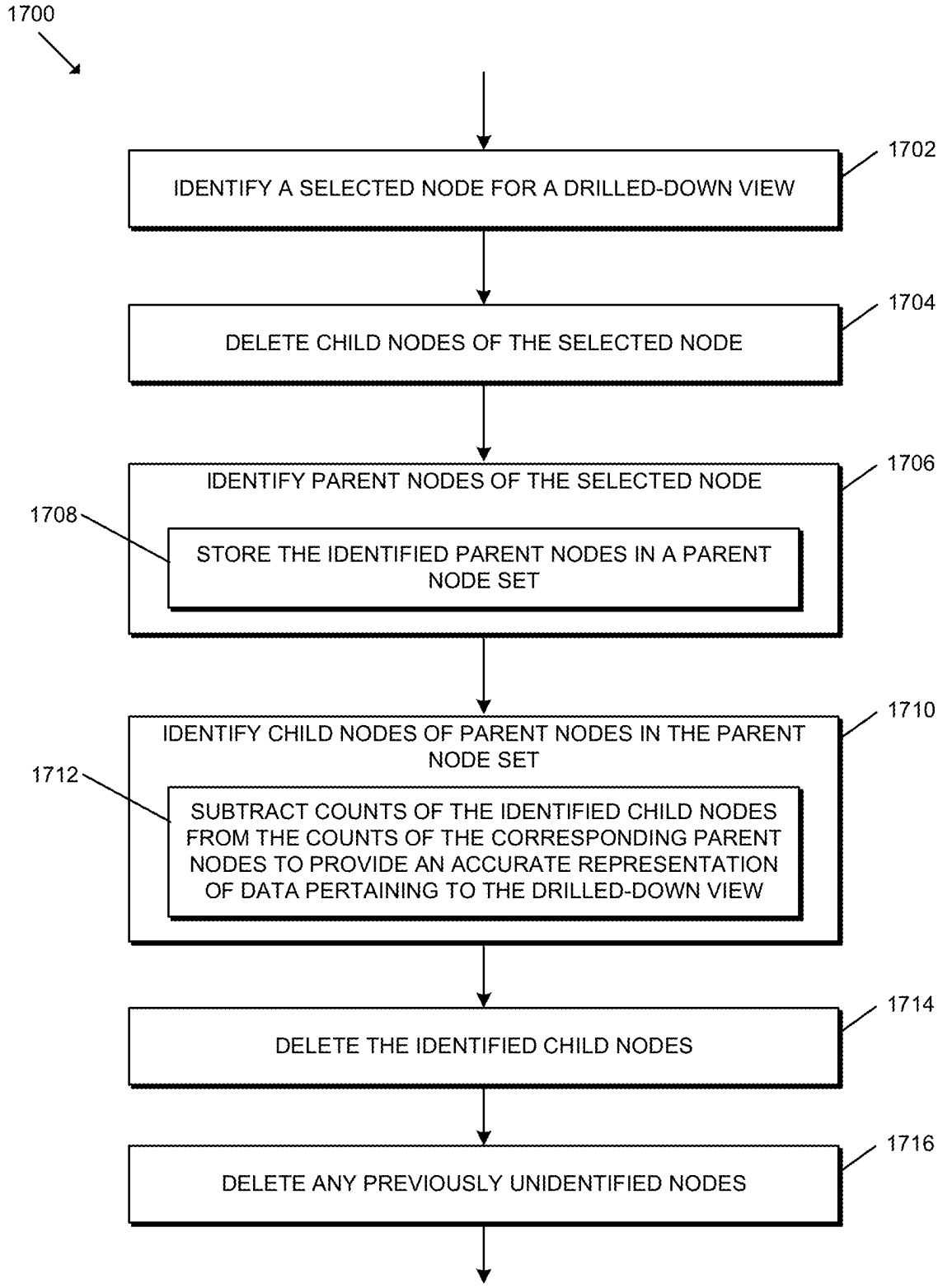

1700
IDENTIFY A SELECTED NODE FOR A DRILLED-DOWN VIEW
1702
DELETE CHILD NODES OF THE SELECTED NODE
1704
IDENTIFY PARENT NODES OF THE SELECTED NODE
1706
1708
STORE THE IDENTIFIED PARENT NODES IN A PARENT NODE SET
IDENTIFY CHILD NODES OF PARENT NODES IN THE PARENT NODE SET
1710
1712
SUBTRACT COUNTS OF THE IDENTIFIED CHILD NODES FROM THE COUNTS OF THE CORRESPONDING PARENT NODES TO PROVIDE AN ACCURATE REPRESENTATION OF DATA PERTAINING TO THE DRILLED-DOWN VIEW
DELETE THE IDENTIFIED CHILD NODES
1714
DELETE ANY PREVIOUSLY UNIDENTIFIED NODES
1716

FIG. 17

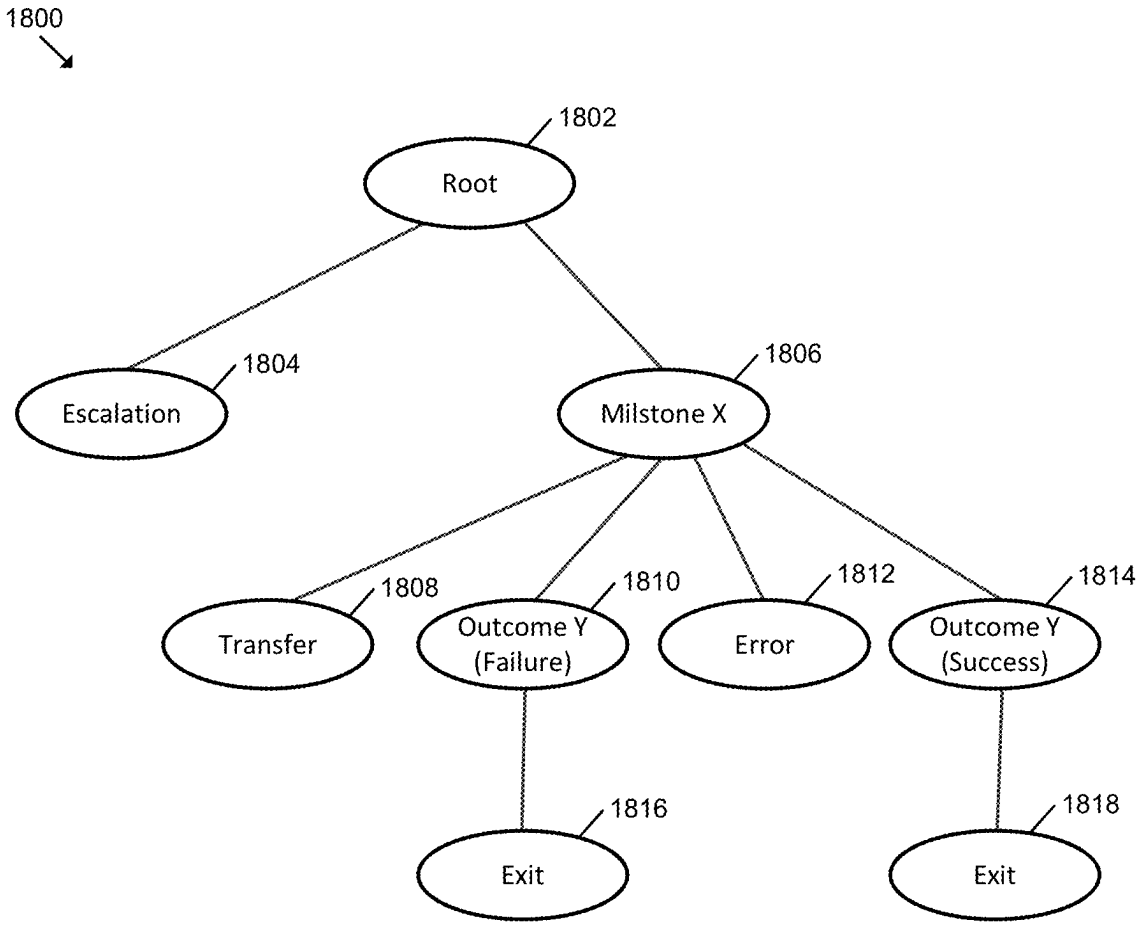

1800
1802
Root
1804
Escalation
1806
Milstone X
1808
Transfer
1810
Outcome Y (Failure)
1812
Error
1814
Outcome Y (Success)
1816
Exit
1818
Exit

FIG. 18

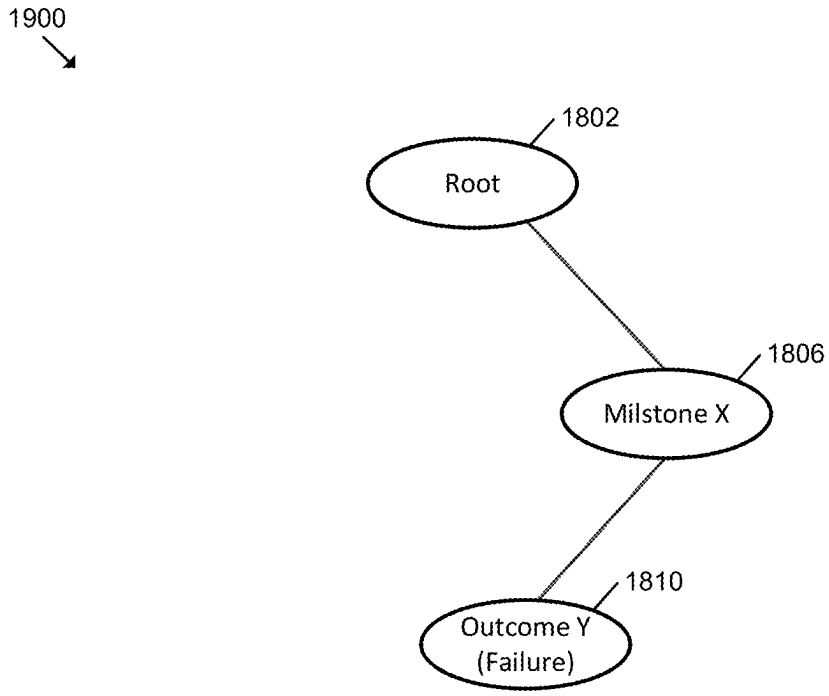



FIG. 19

# EFFICIENT PROCESSING OF TRIE DATA STRUCTURES TO SUPPORT CUSTOMER JOURNEY VISUALIZATIONS

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 63/552,886, titled "ENHANCED GENERATION OF CUSTOMER JOURNEY VISUALIZATIONS VIA USE OF TRIE DATA STRUCTURES," filed on Feb. 13, 2024, the contents of which are incorporated herein by reference in their entirety.

## BACKGROUND

[0002] A customer of a product or service provided by an organization may contact a call center or contact center associated with an organization to obtain support related to the product or service. In doing so, the customer may interact with human and/or virtual agents via electronic communications through technologies including, for example, telephone, email, web chat, Short Message Service (SMS), dedicated software application(s), and/or other technologies. In many scenarios, a customer may be routed among multiple agents as the communication progresses and the type of support and/or the particular agent best suited to provide the requested support is determined.

## SUMMARY

[0003] One embodiment is directed to a unique system, components, and methods for providing efficient trie data structure processing to support customer journey visualizations. Other embodiments are directed to apparatuses, systems, devices, hardware, methods, and combinations thereof for providing efficient trie data structure processing to support customer journey visualizations.

[0004] According to an embodiment, a method for providing efficient trie data structure processing may include splitting, by a computing system and based on organization identifiers and sequence identifiers, a data frame indicative of a set of events associated with customer interactions with automated agents of a contact center to produce a set of multiple partitions. The method may also include producing, by the computing system, a set of multiple trie data structures, including generating a trie data structure for each partition. Each trie data structure may represent aggregate counts of a corresponding subset of event sequences associated with a corresponding organization. The method may also include merging, by the computing system, multiple trie data structures of the set of trie data structures to produce a combined organization trie data structure and storing, by the computing system, the combined organization trie data structure to enable generation of a visualization of the combined organization trie data structure.

[0005] In some embodiments, the method may also include assigning, by the computing system, each partition to a separate execution unit for concurrent processing.

[0006] In some embodiments, the method may also include performing, by the computing system, analytics on the combined organization trie data structure including filtering the combined organization trie data structure as a function of a path category indicative of a type of event that occurred during the customer interactions with the automated agents of the contact center.

[0007] In some embodiments, merging the multiple trie data structures may include identifying a set of unique organization identifiers associated with the multiple trie data structures, repartitioning the data frame based on the organization identifiers and merging trie data structures that are associated with a shared organization identifier.

[0008] In some embodiments, merging the multiple trie data structures may include initializing an empty base trie data structure, reading multiple trie data structures of the set from storage as subtrie data structures, and merging each subtrie data structure into the base trie data structure.

[0009] In some embodiments, merging each subtrie data structure into the base trie data structure may include, for each subtrie data structure, sorting node paths by distance from a root in ascending order and combining a subtrie node with a base trie node in response to a determination that a node path exists in the base trie data structure or adding the subtrie node to the base trie data structure as a new node in response to a determination that the node path does not exist in the base trie data structure.

[0010] In some embodiments, the method may further include tracking, by the computing system, merged nodes of the combined organization trie data structure using a node map and calculating, by the computing system, an edge count for a selected node represented in the node map, including querying the node map to identify the set of merged nodes and summing individual counts associated with the merged nodes.

[0011] In some embodiments, the method may further include identifying, by the computing system, a selected node of the combined organization trie data structure for a drilled-down view in the visualization, identifying, by the computing system, a child node set of one or more child nodes of the selected node, and deleting, by the computing system, the child node set from the visualization.

[0012] In some embodiments, the method may also include identifying a parent node set of one or more parent nodes of the selected node, identifying a set of one or more child nodes of the parent node set, subtracting counts of the identified child nodes from counts of corresponding parent nodes in the parent node set to provide an accurate representation of count data pertaining to the drilled-down view, and deleting the identified child nodes of the parent node set in the drilled-down view.

[0013] According to another embodiment, a system for providing efficient trie data structure processing may include at least one processor and at least one memory comprising a plurality of instructions stored thereon that, in response to execution by the at least one processor, may cause the system to split, based on organization identifiers and sequence identifiers, a data frame indicative of a set of events associated with customer interactions with automated agents of a contact center to produce a set of multiple partitions and produce a set of multiple trie data structures, including generating a trie data structure for each partition. Each trie data structure may represent aggregate counts of a corresponding subset of event sequences associated with a corresponding organization. The plurality of instructions may additionally cause the system to merge multiple trie data structures of the set of trie data structures to produce a combined organization trie data structure and store the combined organization trie data structure to enable generation of a visualization of the combined organization trie data structure.

**[0014]** In some embodiments, the plurality of instructions may further cause the system to assign each partition to a separate execution unit for concurrent processing.

**[0015]** In some embodiments, the plurality of instructions may further cause the system to perform analytics on the combined organization trie data structure including filtering the combined organization trie data structure as a function of a path category indicative of a type of event that occurred during the customer interactions with the automated agents of the contact center.

**[0016]** In some embodiments, to merge the multiple trie data structures may include to identify a set of unique organization identifiers associated with the multiple trie data structures, repartition the data frame based on the organization identifiers, and merge trie data structures that are associated with a shared organization identifier.

**[0017]** In some embodiments, to merge the multiple trie data structures comprises to initialize an empty base trie data structure, read multiple trie data structures of the set from storage as subtrie data structures, and merge each subtrie data structure into the base trie data structure.

**[0018]** In some embodiments, to merge each subtrie data structure into the base trie data structure includes, for each subtrie data structure, to sort node paths by distance from a root in ascending order and combine a subtrie node with a base trie node in response to a determination that a node path exists in the base trie data structure or add the subtrie node to the base trie data structure as a new node in response to a determination that the node path does not exist in the base trie data structure.

**[0019]** In some embodiments, the plurality of instructions may further cause the system to track merged nodes of the combined organization trie data structure using a node map and calculate an edge count for a selected node represented in the node map, including querying the node map to identify the set of merged nodes and summing individual counts associated with the merged nodes.

**[0020]** In some embodiments, the plurality of instructions may further cause the system to identify a selected node of the combined organization trie data structure for a drilled-down view in the visualization, identify a child node set of one or more child nodes of the selected node, and delete the child node set from the visualization.

**[0021]** In some embodiments, the plurality of instructions may further cause the system to identify a parent node set of one or more parent nodes of the selected node, identify a set of one or more child nodes of the parent node set, subtract counts of the identified child nodes from counts of corresponding parent nodes in the parent node set to provide an accurate representation of count data pertaining to the drilled-down view, and delete the identified child nodes of the parent node set in the drilled-down view.

**[0022]** According to yet another embodiment, one or more non-transitory machine-readable storage media may include a plurality of instructions stored thereon that, in response to execution by a computing system, may cause the computing system to split, based on organization identifiers and sequence identifiers, a data frame indicative of a set of events associated with customer interactions with automated agents of a contact center to produce a set of multiple partitions and produce a set of multiple trie data structures, including generating a trie data structure for each partition. Each trie data structure may represent aggregate counts of a corresponding subset of event sequences associated with a corresponding organization. The plurality of instructions may also cause the computing system to merge multiple trie data structures of the set of trie data structures to produce a combined organization trie data structure and store the combined organization trie data structure to enable generation of a visualization of the combined organization trie data structure.

**[0023]** In some embodiments, the plurality of instructions may further cause the computing system to assign each partition to a separate execution unit for concurrent processing.

**[0024]** This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter. Further embodiments, forms, features, and aspects of the present application shall become apparent from the descriptions and figures provided herewith.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0025]** The concepts described herein are illustrative by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. Where considered appropriate, references labels have been repeated among the figures to indicate corresponding or analogous elements.

**[0026]** FIG. **1** depicts a simplified block diagram of at least one embodiment of a contact center system;

**[0027]** FIG. **2** is a simplified block diagram of at least one embodiment of a computing device;

**[0028]** FIG. **3** is a simplified flow diagram of at least one embodiment of a method for filtering a trie data structure by a specific event;

**[0029]** FIG. **4** is a simplified flow diagram of at least one embodiment a method for filtering a trie data structure by an event attribute;

**[0030]** FIG. **5** is a simplified flow diagram of at least one embodiment of a method for filtering a trie data structure by a bot flow;

**[0031]** FIGS. **6-7** illustrate various states of an example trie data structure being filtered by a specific event;

**[0032]** FIGS. **8-10** illustrate various states of an example trie data structure being filtered by an event attribute;

**[0033]** FIGS. **11-12** illustrate various states of an example trie data structure being filtered by a bot flow;

**[0034]** FIGS. **13-14** are a simplified flow diagram of a method for partitioning data for efficient processing of trie data structures;

**[0035]** FIG. **15** is a simplified flow diagram of a method for merging trie data structures into a combined trie data structure;

**[0036]** FIG. **16** is a simplified flow diagram of a method for calculating accurate edge counts for a node associated with a trie data structure;

**[0037]** FIG. **17** is a simplified flow diagram of a method for calculating accurate count data for a drilled-down view in a visualization of a trie data structure; and

**[0038]** FIGS. **18-19** illustrate different states of a trie data structure associated with a visualization.

## DETAILED DESCRIPTION

**[0039]** Although the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described herein in detail. It should be understood, however, that there is no intent to limit the concepts of the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives consistent with the present disclosure and the appended claims.

**[0040]** References in the specification to "one embodiment," "an embodiment," "an illustrative embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may or may not necessarily include that particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. It should be further appreciated that although reference to a "preferred" component or feature may indicate the desirability of a particular component or feature with respect to an embodiment, the disclosure is not so limiting with respect to other embodiments, which may omit such a component or feature. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to implement such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. Further, particular features, structures, or characteristics may be combined in any suitable combinations and/or sub-combinations in various embodiments.

**[0041]** Additionally, it should be appreciated that items included in a list in the form of "at least one of A, B, and C" can mean (A); (B); (C); (A and B); (B and C); (A and C); or (A, B, and C). Similarly, items listed in the form of "at least one of A, B, or C" can mean (A); (B); (C); (A and B); (B and C); (A and C); or (A, B, and C). Further, with respect to the claims, the use of words and phrases such as "a," "an," "at least one," and/or "at least one portion" should not be interpreted so as to be limiting to only one such element unless specifically stated to the contrary, and the use of phrases such as "at least a portion" and/or "a portion" should be interpreted as encompassing both embodiments including only a portion of such element and embodiments including the entirety of such element unless specifically stated to the contrary.

**[0042]** The disclosed embodiments may, in some cases, be implemented in hardware, firmware, software, or a combination thereof. The disclosed embodiments may also be implemented as instructions carried by or stored on one or more transitory or non-transitory machine-readable (e.g., computer-readable) storage media, which may be read and executed by one or more processors. A machine-readable storage medium may be embodied as any storage device, mechanism, or other physical structure for storing or transmitting information in a form readable by a machine (e.g., a volatile or non-volatile memory, a media disc, or other media device).

**[0043]** In the drawings, some structural or method features may be shown in specific arrangements and/or orderings. However, it should be appreciated that such specific arrangements and/or orderings may not be required. Rather, in some embodiments, such features may be arranged in a different manner and/or order than shown in the illustrative figures unless indicated to the contrary. Additionally, the inclusion of a structural or method feature in a particular figure is not meant to imply that such feature is required in all embodiments and, in some embodiments, may not be included or may be combined with other features.

**[0044]** The technologies described herein pertain to customer relations services and customer relations management via contact centers and associated cloud-based systems. More particularly, the technologies described herein enable the generation of user-friendly visualizations that assist customer-experience managers of contact centers to improve the "big picture" experience of customers in their interactions with agents associated with the contact center, including automated agents ("bots"). The visualizations may include, for example, flow milestones and outcomes of interactions. In enabling the generation of visualizations, the illustrative technologies may utilize a trie data structure while providing functionality for filtering, searching, and querying to show events in customers' journeys starting at a particular event, events that include a particular attribute value, and/or events associated with a particular bot flow (e.g., executed by a bot or automated agent of the contact center system). Further, technologies described herein may allow for the efficient processing of trie data structures, including merging such data structures while maintaining data fidelity, to enhance the generation of customer journey visualizations and related analytics. For example, embodiments provided herein include techniques for split processing and merging of tries for relatively large organizations, to provide increased computational efficiency and system reliability. Further embodiments are provided that ensure that counts of inflow and outflow at each node in a trie data structure are equal in a visualization of pathways (e.g., sequences of events represented by the nodes).

**[0045]** Trie data structure implementations traditionally have drawbacks that limit their capabilities in certain use cases. For example, to enable filtering and querying capabilities based on any event and visualizing paths to/from that event, it is possible to simply create multiple trie data structures, with one trie data structure for each event or node within the trie data structure. However, such an approach is computationally intensive and leads to significant scalability issues. Accordingly, the technologies described herein provide for a scalable solution that permits such types of filtering and querying using trie data structures (i.e., without building separate tries for each query event). Further, the technologies described herein allow for an online (e.g., cloud-based) computational approach while maintaining reasonable latency (e.g., latency that satisfies typical service level agreement requirements, such as maximum query responses of one second). Instead of creating a trie for each filtering criterion, a single "big picture" trie may be stored for each organization, which includes each of the bot flows and associated event attributes. This approach significantly reduces the processing and read/write operations required, resulting in improved efficiency. The reduced number of files and their corresponding read/write operations also result in lower operational cost. The system can also seamlessly integrate with various bot flows, allowing for diverse and customizable functionalities.

**[0046]** The technologies provided herein enable efficient processing of event data that forms a basis for producing trie data structures to be represented in a visualization of a customer journey. As described in more detail herein, in at

least some embodiments, the efficient processing includes splitting event data in a data frame into multiple partitions, producing trie data structures based on each of those partitions, and selectively merging trie data structures based on the organization associated with each trie data structure. By partitioning the data frame, the technologies described herein enable generation of the corresponding trie data structures in parallel, such as with corresponding execution units (e.g., processing devices), rather than over burdening a single execution unit with the task of generating a trie data structure from a relatively large data frame. Additionally, embodiments of the technology described in more herein enable operations to accurately track count data indicative of inflows and outflows from nodes of a trie data structure. Further, and as described in more detail, the operations may include updating count data associated with a selected portion of a trie data structure to enable an accurate drilled-down view of the portion of the trie data structure. Accordingly, a system implementing the technologies provided herein may make more efficient use of available processing capacity (e.g., available cycles of processing devices) to generate a trie data structure for a given organization and may perform operations to ensure that accurate count information is determined for nodes of a trie data structure represented in a visualization.

**[0047]** It should be appreciated that a "trie data structure" may be simply referred to herein as a "trie" for simplicity and brevity of the description. Further, although the technologies are described herein in reference to "bot flows," it should be appreciated that similar technologies may be applied to other types of flows or client journeys in other embodiments.

**[0048]** Referring now to FIG. **1**, a simplified block diagram of at least one embodiment of a communications infrastructure and/or contact center system, which may be used in conjunction with one or more of the embodiments described herein, is shown. The contact center system **100** may be embodied as any system capable of providing contact center services (e.g., call center services, chat center services, SMS center services, etc.) to a customer and otherwise performing the functions described herein. The illustrative contact center system **100** includes a customer device **102**, a network **104**, a switch/media gateway **106**, a call controller **108**, an interactive media response (IMR) server **110**, a routing server **112**, a storage device **114**, a statistics server **116**, agent devices **118**A, **118**B, **118**C, a media server **120**, a knowledge management server **122**, a knowledge system **124**, chat server **126**, web servers **128**, an interaction (iXn) server **130**, a universal contact server **132**, a reporting server **134**, a media services server **136**, and an analytics module **138**. Although only one customer device **102**, one network **104**, one switch/media gateway **106**, one call controller **108**, one IMR server **110**, one routing server **112**, one storage device **114**, one statistics server **116**, one media server **120**, one knowledge management server **122**, one knowledge system **124**, one chat server **126**, one iXn server **130**, one universal contact server **132**, one reporting server **134**, one media services server **136**, and one analytics module **138** are shown in the illustrative embodiment of FIG. **1**, the contact center system **100** may include multiple customer devices **102**, networks **104**, switch/media gateways **106**, call controllers **108**, IMR servers **110**, routing servers **112**, storage devices **114**, statistics servers **116**, media servers **120**, knowledge management servers **122**, knowledge systems **124**, chat servers **126**, iXn servers **130**, universal contact servers **132**, reporting servers **134**, media services servers **136**, and/or analytics modules **138** in other embodiments. Further, in some embodiments, one or more of the components described herein may be excluded from the system **100**, one or more of the components described as being independent may form a portion of another component, and/or one or more of the component described as forming a portion of another component may be independent.

**[0049]** It should be understood that the term "contact center system" is used herein to refer to the system depicted in FIG. **1** and/or the components thereof, while the term "contact center" is used more generally to refer to contact center systems, customer service providers operating those systems, and/or the organizations or enterprises associated therewith. Thus, unless otherwise specifically limited, the term "contact center" refers generally to a contact center system (such as the contact center system **100**), the associated customer service provider (such as a particular customer service provider/agent providing customer services through the contact center system **100**), as well as the organization or enterprise on behalf of which those customer services are being provided.

**[0050]** By way of background, customer service providers may offer many types of services through contact centers. Such contact centers may be staffed with employees or customer service agents (or simply "agents"), with the agents serving as an interface between a company, enterprise, government agency, or organization (hereinafter referred to interchangeably as an "organization" or "enterprise") and persons, such as users, individuals, or customers (hereinafter referred to interchangeably as "individuals," "customers," or "contact center clients"). For example, the agents at a contact center may assist customers in making purchasing decisions, receiving orders, or solving problems with products or services already received. Within a contact center, such interactions between contact center agents and outside entities or customers may be conducted over a variety of communication channels, such as, for example, via voice (e.g., telephone calls or voice over IP or VoIP calls), video (e.g., video conferencing), text (e.g., emails and text chat), screen sharing, co-browsing, and/or other communication channels.

**[0051]** Operationally, contact centers generally strive to provide quality services to customers while minimizing costs. For example, one way for a contact center to operate is to handle every customer interaction with a live agent. While this approach may score well in terms of the service quality, it likely would also be prohibitively expensive due to the high cost of agent labor. Because of this, most contact centers utilize some level of automated processes in place of live agents, such as, for example, interactive voice response (IVR) systems, interactive media response (IMR) systems, internet robots or "bots," automated chat modules or "chatbots," and/or other automated processed. In many cases, this has proven to be a successful strategy, as automated processes can be highly efficient in handling certain types of interactions and effective at decreasing the need for live agents. Such automation allows contact centers to target the use of human agents for the more difficult customer interactions, while the automated processes handle the more repetitive or routine tasks. Further, automated processes can be structured in a way that optimizes efficiency and pro-

motes repeatability. Whereas a human or live agent may forget to ask certain questions or follow-up on particular details, such mistakes are typically avoided through the use of automated processes. While customer service providers are increasingly relying on automated processes to interact with customers, the use of such technologies by customers remains far less developed. Thus, while IVR systems, IMR systems, and/or bots are used to automate portions of the interaction on the contact center-side of an interaction, the actions on the customer-side remain for the customer to perform manually.

**[0052]** It should be appreciated that the contact center system **100** may be used by a customer service provider to provide various types of services to customers. For example, the contact center system **100** may be used to engage and manage interactions in which automated processes (or bots) or human agents communicate with customers. As should be understood, the contact center system **100** may be an in-house facility to a business or enterprise for performing the functions of sales and customer service relative to products and services available through the enterprise. In another embodiment, the contact center system **100** may be operated by a third-party service provider that contracts to provide services for another organization. Further, the contact center system **100** may be deployed on equipment dedicated to the enterprise or third-party service provider, and/or deployed in a remote computing environment such as, for example, a private or public cloud environment with infrastructure for supporting multiple contact centers for multiple enterprises. The contact center system **100** may include software applications or programs, which may be executed on premises or remotely or some combination thereof. It should further be appreciated that the various components of the contact center system **100** may be distributed across various geographic locations and not necessarily contained in a single location or computing environment.

**[0053]** It should further be understood that, unless otherwise specifically limited, any of the computing elements of the present invention may be implemented in cloud-based or cloud computing environments. As used herein and further described below in reference to the computing device **200**, "cloud computing"—or, simply, the "cloud"—is defined as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned via virtualization and released with minimal management effort or service provider interaction, and then scaled accordingly. Cloud computing can be composed of various characteristics (e.g., on-demand self-service, broad network access, resource pooling, rapid elasticity, measured service, etc.), service models (e.g., Software as a Service ("SaaS"), Platform as a Service ("PaaS"), Infrastructure as a Service ("IaaS"), and deployment models (e.g., private cloud, community cloud, public cloud, hybrid cloud, etc.). Often referred to as a "serverless architecture," a cloud execution model generally includes a service provider dynamically managing an allocation and provisioning of remote servers for achieving a desired functionality.

**[0054]** It should be understood that any of the computer-implemented components, modules, or servers described in relation to FIG. **1** may be implemented via one or more types of computing devices, such as, for example, the computing device **200** of FIG. **2**. As will be seen, the contact center system **100** generally manages resources (e.g., personnel, computers, telecommunication equipment, etc.) to enable delivery of services via telephone, email, chat, or other communication mechanisms. Such services may vary depending on the type of contact center and, for example, may include customer service, help desk functionality, emergency response, telemarketing, order taking, and/or other characteristics.

**[0055]** Customers desiring to receive services from the contact center system **100** may initiate inbound communications (e.g., telephone calls, emails, chats, etc.) to the contact center system **100** via a customer device **102**. While FIG. **1** shows one such customer device—i.e., customer device **102**—it should be understood that any number of customer devices **102** may be present. The customer devices **102**, for example, may be a communication device, such as a telephone, smart phone, computer, tablet, or laptop. In accordance with functionality described herein, customers may generally use the customer devices **102** to initiate, manage, and conduct communications with the contact center system **100**, such as telephone calls, emails, chats, text messages, web-browsing sessions, and other multi-media transactions.

**[0056]** Inbound and outbound communications from and to the customer devices **102** may traverse the network **104**, with the nature of the network typically depending on the type of customer device being used and the form of communication. As an example, the network **104** may include a communication network of telephone, cellular, and/or data services. The network **104** may be a private or public switched telephone network (PSTN), local area network (LAN), private wide area network (WAN), and/or public WAN such as the Internet. Further, the network **104** may include a wireless carrier network including a code division multiple access (CDMA) network, global system for mobile communications (GSM) network, or any wireless network/technology conventional in the art, including but not limited to 3G, 4G, LTE, 5G, etc.

**[0057]** The switch/media gateway **106** may be coupled to the network **104** for receiving and transmitting telephone calls between customers and the contact center system **100**. The switch/media gateway **106** may include a telephone or communication switch configured to function as a central switch for agent level routing within the center. The switch may be a hardware switching system or implemented via software. For example, the switch **106** may include an automatic call distributor, a private branch exchange (PBX), an IP-based software switch, and/or any other switch with specialized hardware and software configured to receive Internet-sourced interactions and/or telephone network-sourced interactions from a customer, and route those interactions to, for example, one of the agent devices **118**. Thus, in general, the switch/media gateway **106** establishes a voice connection between the customer and the agent by establishing a connection between the customer device **102** and agent device **118**.

**[0058]** As further shown, the switch/media gateway **106** may be coupled to the call controller **108** which, for example, serves as an adapter or interface between the switch and the other routing, monitoring, and communication-handling components of the contact center system **100**. The call controller **108** may be configured to process PSTN calls, VoIP calls, and/or other types of calls. For example, the call controller **108** may include computer-telephone integra-

tion (CTI) software for interfacing with the switch/media gateway and other components. The call controller **108** may include a session initiation protocol (SIP) server for processing SIP calls. The call controller **108** may also extract data about an incoming interaction, such as the customer's telephone number, IP address, or email address, and then communicate these with other contact center components in processing the interaction.

**[0059]** The interactive media response (IMR) server **110** may be configured to enable self-help or virtual assistant functionality. Specifically, the IMR server **110** may be similar to an interactive voice response (IVR) server, except that the IMR server **110** is not restricted to voice and may also cover a variety of media channels. In an example illustrating voice, the IMR server **110** may be configured with an IMR script for querying customers on their needs. For example, a contact center for a bank may instruct customers via the IMR script to "press 1" if they wish to retrieve their account balance. Through continued interaction with the IMR server **110**, customers may receive service without needing to speak with an agent. The IMR server **110** may also be configured to ascertain why a customer is contacting the contact center so that the communication may be routed to the appropriate resource. The IMR configuration may be performed through the use of a self-service and/or assisted service tool which comprises a web-based tool for developing IVR applications and routing applications running in the contact center environment.

**[0060]** The routing server **112** may function to route incoming interactions. For example, once it is determined that an inbound communication should be handled by a human agent, functionality within the routing server **112** may select the most appropriate agent and route the communication thereto. This agent selection may be based on which available agent is best suited for handling the communication. More specifically, the selection of appropriate agent may be based on a routing strategy or algorithm that is implemented by the routing server **112**. In doing this, the routing server **112** may query data that is relevant to the incoming interaction, for example, data relating to the particular customer, available agents, and the type of interaction, which, as described herein, may be stored in particular databases. Once the agent is selected, the routing server **112** may interact with the call controller **108** to route (i.e., connect) the incoming interaction to the corresponding agent device **118**. As part of this connection, information about the customer may be provided to the selected agent via their agent device **118**. This information is intended to enhance the service the agent is able to provide to the customer.

**[0061]** It should be appreciated that the contact center system **100** may include one or more mass storage devices—represented generally by the storage device **114**—for storing data in one or more databases relevant to the functioning of the contact center. For example, the storage device **114** may store customer data that is maintained in a customer database. Such customer data may include, for example, customer profiles, contact information, service level agreement (SLA), and interaction history (e.g., details of previous interactions with a particular customer, including the nature of previous interactions, disposition data, wait time, handle time, and actions taken by the contact center to resolve customer issues). As another example, the storage device **114** may store agent data in an agent database. Agent data maintained by the contact center system **100** may include, for example, agent availability and agent profiles, schedules, skills, handle time, and/or other relevant data. As another example, the storage device **114** may store interaction data in an interaction database. Interaction data may include, for example, data relating to numerous past interactions between customers and contact centers. More generally, it should be understood that, unless otherwise specified, the storage device **114** may be configured to include databases and/or store data related to any of the types of information described herein, with those databases and/or data being accessible to the other modules or servers of the contact center system **100** in ways that facilitate the functionality described herein. For example, the servers or modules of the contact center system **100** may query such databases to retrieve data stored therein or transmit data thereto for storage. The storage device **114**, for example, may take the form of any conventional storage medium and may be locally housed or operated from a remote location. As an example, the databases may be Cassandra database, NoSQL database, or a SQL database and managed by a database management system, such as, Oracle, IBM DB2, Microsoft SQL server, or Microsoft Access, PostgreSQL.

**[0062]** The statistics server **116** may be configured to record and aggregate data relating to the performance and operational aspects of the contact center system **100**. Such information may be compiled by the statistics server **116** and made available to other servers and modules, such as the reporting server **134**, which then may use the data to produce reports that are used to manage operational aspects of the contact center and execute automated actions in accordance with functionality described herein. Such data may relate to the state of contact center resources, e.g., average wait time, abandonment rate, agent occupancy, and others as functionality described herein would require.

**[0063]** The agent devices **118** of the contact center system **100** may be communication devices configured to interact with the various components and modules of the contact center system **100** in ways that facilitate functionality described herein. An agent device **118**, for example, may include a telephone adapted for regular telephone calls or VoIP calls. An agent device **118** may further include a computing device configured to communicate with the servers of the contact center system **100**, perform data processing associated with operations, and interface with customers via voice, chat, email, and other multimedia communication mechanisms according to functionality described herein. Although FIG. **1** shows three such agent devices **118**—i.e., agent devices **118**A, **118**B and **118**C—it should be understood that any number of agent devices **118** may be present in a particular embodiment.

**[0064]** The multimedia/social media server **120** may be configured to facilitate media interactions (other than voice) with the customer devices **102** and/or the servers **128**. Such media interactions may be related, for example, to email, voice mail, chat, video, text-messaging, web, social media, co-browsing, etc. The multimedia/social media server **120** may take the form of any IP router conventional in the art with specialized hardware and software for receiving, processing, and forwarding multi-media events and communications.

**[0065]** The knowledge management server **122** may be configured to facilitate interactions between customers and the knowledge system **124**. In general, the knowledge sys-

tem **124** may be a computer system capable of receiving questions or queries and providing answers in response. The knowledge system **124** may be included as part of the contact center system **100** or operated remotely by a third party. The knowledge system **124** may include an artificially intelligent computer system capable of answering questions posed in natural language by retrieving information from information sources such as encyclopedias, dictionaries, newswire articles, literary works, or other documents submitted to the knowledge system **124** as reference materials. As an example, the knowledge system **124** may be embodied as IBM Watson or a similar system.

**[0066]** The chat server **126**, it may be configured to conduct, orchestrate, and manage electronic chat communications with customers. In general, the chat server **126** is configured to implement and maintain chat conversations and generate chat transcripts. Such chat communications may be conducted by the chat server **126** in such a way that a customer communicates with automated chatbots, human agents, or both. In exemplary embodiments, the chat server **126** may perform as a chat orchestration server that dispatches chat conversations among the chatbots and available human agents. In such cases, the processing logic of the chat server **126** may be rules driven so to leverage an intelligent workload distribution among available chat resources. The chat server **126** further may implement, manage, and facilitate user interfaces (UIs) associated with the chat feature, including those UIs generated at either the customer device **102** or the agent device **118**. The chat server **126** may be configured to transfer chats within a single chat session with a particular customer between automated and human sources such that, for example, a chat session transfers from a chatbot to a human agent or from a human agent to a chatbot. The chat server **126** may also be coupled to the knowledge management server **122** and the knowledge systems **124** for receiving suggestions and answers to queries posed by customers during a chat so that, for example, links to relevant articles can be provided.

**[0067]** The web servers **128** may be included to provide site hosts for a variety of social interaction sites to which customers subscribe, such as Facebook, Twitter, Instagram, etc. Though depicted as part of the contact center system **100**, it should be understood that the web servers **128** may be provided by third parties and/or maintained remotely. The web servers **128** may also provide webpages for the enterprise or organization being supported by the contact center system **100**. For example, customers may browse the webpages and receive information about the products and services of a particular enterprise. Within such enterprise webpages, mechanisms may be provided for initiating an interaction with the contact center system **100**, for example, via web chat, voice, or email. An example of such a mechanism is a widget, which can be deployed on the webpages or websites hosted on the web servers **128**. As used herein, a widget refers to a user interface component that performs a particular function. In some implementations, a widget may include a graphical user interface control that can be overlaid on a webpage displayed to a customer via the Internet. The widget may show information, such as in a window or text box, or include buttons or other controls that allow the customer to access certain functionalities, such as sharing or opening a file or initiating a communication. In some implementations, a widget includes a user interface component having a portable portion of code that can be installed and executed within a separate webpage without compilation. Some widgets can include corresponding or additional user interfaces and be configured to access a variety of local resources (e.g., a calendar or contact information on the customer device) or remote resources via network (e.g., instant messaging, electronic mail, or social networking updates).

**[0068]** The interaction (iXn) server **130** may be configured to manage deferrable activities of the contact center and the routing thereof to human agents for completion. As used herein, deferrable activities may include back-office work that can be performed off-line, e.g., responding to emails, attending training, and other activities that do not entail real-time communication with a customer. As an example, the interaction (iXn) server **130** may be configured to interact with the routing server **112** for selecting an appropriate agent to handle each of the deferrable activities. Once assigned to a particular agent, the deferrable activity is pushed to that agent so that it appears on the agent device **118** of the selected agent. The deferrable activity may appear in a workbin as a task for the selected agent to complete. The functionality of the workbin may be implemented via any conventional data structure, such as, for example, a linked list, array, and/or other suitable data structure. Each of the agent devices **118** may include a workbin. As an example, a workbin may be maintained in the buffer memory of the corresponding agent device **118**.

**[0069]** The universal contact server (UCS) **132** may be configured to retrieve information stored in the customer database and/or transmit information thereto for storage therein. For example, the UCS **132** may be utilized as part of the chat feature to facilitate maintaining a history on how chats with a particular customer were handled, which then may be used as a reference for how future chats should be handled. More generally, the UCS **132** may be configured to facilitate maintaining a history of customer preferences, such as preferred media channels and best times to contact. To do this, the UCS **132** may be configured to identify data pertinent to the interaction history for each customer such as, for example, data related to comments from agents, customer communication history, and the like. Each of these data types then may be stored in the customer database **222** or on other modules and retrieved as functionality described herein requires.

**[0070]** The reporting server **134** may be configured to generate reports from data compiled and aggregated by the statistics server **116** or other sources. Such reports may include near real-time reports or historical reports and concern the state of contact center resources and performance characteristics, such as, for example, average wait time, abandonment rate, and/or agent occupancy. The reports may be generated automatically or in response to specific requests from a requestor (e.g., agent, administrator, contact center application, etc.). The reports then may be used toward managing the contact center operations in accordance with functionality described herein.

**[0071]** The media services server **136** may be configured to provide audio and/or video services to support contact center features. In accordance with functionality described herein, such features may include prompts for an IVR or IMR system (e.g., playback of audio files), hold music, voicemails/single party recordings, multi-party recordings (e.g., of audio and/or video calls), screen recording, speech recognition, dual tone multi frequency (DTMF) recognition,

faxes, audio and video transcoding, secure real-time transport protocol (SRTP), audio conferencing, video conferencing, coaching (e.g., support for a coach to listen in on an interaction between a customer and an agent and for the coach to provide comments to the agent without the customer hearing the comments), call analysis, keyword spotting, and/or other relevant features.

**[0072]** The analytics module **138** may be configured to provide systems and methods for performing analytics on data received from a plurality of different data sources as functionality described herein may require. In accordance with example embodiments, the analytics module **138** also may generate, update, train, and modify predictors or models based on collected data, such as, for example, customer data, agent data, and interaction data. The models may include behavior models of customers or agents. The behavior models may be used to predict behaviors of, for example, customers or agents, in a variety of situations, thereby allowing embodiments of the present invention to tailor interactions based on such predictions or to allocate resources in preparation for predicted characteristics of future interactions, thereby improving overall contact center performance and the customer experience. It will be appreciated that, while the analytics module is described as being part of a contact center, such behavior models also may be implemented on customer systems (or, as also used herein, on the "customer-side" of the interaction) and used for the benefit of customers.

**[0073]** According to exemplary embodiments, the analytics module **138** may have access to the data stored in the storage device **114**, including the customer database and agent database. The analytics module **138** also may have access to the interaction database, which stores data related to interactions and interaction content (e.g., transcripts of the interactions and events detected therein), interaction metadata (e.g., customer identifier, agent identifier, medium of interaction, length of interaction, interaction start and end time, department, tagged categories), and the application setting (e.g., the interaction path through the contact center). Further, the analytic module **138** may be configured to retrieve data stored within the storage device **114** for use in developing and training algorithms and models, for example, by applying machine learning techniques.

**[0074]** One or more of the included models may be configured to predict customer or agent behavior and/or aspects related to contact center operation and performance. Further, one or more of the models may be used in natural language processing and, for example, include intent recognition and the like. The models may be developed based upon known first principle equations describing a system; data, resulting in an empirical model; or a combination of known first principle equations and data. In developing a model for use with present embodiments, because first principles equations are often not available or easily derived, it may be generally preferred to build an empirical model based upon collected and stored data. To properly capture the relationship between the manipulated/disturbance variables and the controlled variables of complex systems, in some embodiments, it may be preferable that the models are nonlinear. This is because nonlinear models can represent curved rather than straight-line relationships between manipulated/disturbance variables and controlled variables, which are common to complex systems such as those discussed herein. Given the foregoing requirements, a machine learning or neural network-based approach may be a preferred embodiment for implementing the models. Neural networks, for example, may be developed based upon empirical data using advanced regression algorithms.

**[0075]** The analytics module **138** may further include an optimizer. As will be appreciated, an optimizer may be used to minimize a "cost function" subject to a set of constraints, where the cost function is a mathematical representation of desired objectives or system operation. Because the models may be non-linear, the optimizer may be a nonlinear programming optimizer. It is contemplated, however, that the technologies described herein may be implemented by using, individually or in combination, a variety of different types of optimization approaches, including, but not limited to, linear programming, quadratic programming, mixed integer non-linear programming, stochastic programming, global non-linear programming, genetic algorithms, particle/swarm techniques, and the like.

**[0076]** According to some embodiments, the models and the optimizer may together be used within an optimization system. For example, the analytics module **138** may utilize the optimization system as part of an optimization process by which aspects of contact center performance and operation are optimized or, at least, enhanced. This, for example, may include features related to the customer experience, agent experience, interaction routing, natural language processing, intent recognition, or other functionality related to automated processes.

**[0077]** The various components, modules, and/or servers of FIG. **1** (as well as the other figures included herein) may each include one or more processors executing computer program instructions and interacting with other system components for performing the various functionalities described herein. Such computer program instructions may be stored in a memory implemented using a standard memory device, such as, for example, a random-access memory (RAM), or stored in other non-transitory computer readable media such as, for example, a CD-ROM, flash drive, etc. Although the functionality of each of the servers is described as being provided by the particular server, a person of skill in the art should recognize that the functionality of various servers may be combined or integrated into a single server, or the functionality of a particular server may be distributed across one or more other servers without departing from the scope of the present invention. Further, the terms "interaction" and "communication" are used interchangeably, and generally refer to any real-time and non-real-time interaction that uses any communication channel including, without limitation, telephone calls (PSTN or VoIP calls), emails, vmails, video, chat, screen-sharing, text messages, social media messages, WebRTC calls, etc. Access to and control of the components of the contact center system **100** may be affected through user interfaces (UIs) which may be generated on the customer devices **102** and/or the agent devices **118**.

**[0078]** As noted above, in some embodiments, the contact center system **100** may operate as a hybrid system in which some or all components are hosted remotely, such as in a cloud-based or cloud computing environment. It should be appreciated that each of the devices of the contact center system **100** may be embodied as, include, or form a portion of one or more computing devices similar to the computing device **200** described below in reference to FIG. **2**.

**[0079]** Referring now to FIG. **2**, a simplified block diagram of at least one embodiment of a computing device **200**

is shown. The illustrative computing device **200** depicts at least one embodiment of each of the computing devices, systems, servicers, controllers, switches, gateways, engines, modules, and/or computing components described herein (e.g., which collectively may be referred to interchangeably as computing devices, servers, or modules for brevity of the description). For example, the various computing devices may be a process or thread running on one or more processors of one or more computing devices **200**, which may be executing computer program instructions and interacting with other system modules in order to perform the various functionalities described herein. Unless otherwise specifically limited, the functionality described in relation to a plurality of computing devices may be integrated into a single computing device, or the various functionalities described in relation to a single computing device may be distributed across several computing devices. Further, in relation to the computing systems described herein—such as the contact center system **100** of FIG. **1**—the various servers and computer devices thereof may be located on local computing devices **200** (e.g., on-site at the same physical location as the agents of the contact center), remote computing devices **200** (e.g., off-site or in a cloud-based or cloud computing environment, for example, in a remote data center connected via a network), or some combination thereof. In some embodiments, functionality provided by servers located on computing devices off-site may be accessed and provided over a virtual private network (VPN), as if such servers were on-site, or the functionality may be provided using a software as a service (SaaS) accessed over the Internet using various protocols, such as by exchanging data via extensible markup language (XML), JSON, and/or the functionality may be otherwise accessed/leveraged.

**[0080]** In some embodiments, the computing device **200** may be embodied as a server, desktop computer, laptop computer, tablet computer, notebook, netbook, Ultrabook™, cellular phone, mobile computing device, smartphone, wearable computing device, personal digital assistant, Internet of Things (IoT) device, processing system, wireless access point, router, gateway, and/or any other computing, processing, and/or communication device capable of performing the functions described herein.

**[0081]** The computing device **200** includes a processing device **202** that executes algorithms and/or processes data in accordance with operating logic **208**, an input/output device **204** that enables communication between the computing device **200** and one or more external devices **210**, and memory **206** which stores, for example, data received from the external device **210** via the input/output device **204**.

**[0082]** The input/output device **204** allows the computing device **200** to communicate with the external device **210**. For example, the input/output device **204** may include a transceiver, a network adapter, a network card, an interface, one or more communication ports (e.g., a USB port, serial port, parallel port, an analog port, a digital port, VGA, DVI, HDMI, Fire Wire, CAT 5, or any other type of communication port or interface), and/or other communication circuitry. Communication circuitry of the computing device **200** may be configured to use any one or more communication technologies (e.g., wireless or wired communications) and associated protocols (e.g., Ethernet, Bluetooth®, Wi-Fi®, WiMAX, etc.) to effect such communication depending on the particular computing device **200**. The input/output device **204** may include hardware, software, and/or firmware suitable for performing the techniques described herein.

**[0083]** The external device **210** may be any type of device that allows data to be inputted or outputted from the computing device **200**. For example, in various embodiments, the external device **210** may be embodied as one or more of the devices/systems described herein, and/or a portion thereof. Further, in some embodiments, the external device **210** may be embodied as another computing device, switch, diagnostic tool, controller, printer, display, alarm, peripheral device (e.g., keyboard, mouse, touch screen display, etc.), and/or any other computing, processing, and/or communication device capable of performing the functions described herein. Furthermore, in some embodiments, it should be appreciated that the external device **210** may be integrated into the computing device **200**.

**[0084]** The processing device **202** may be embodied as any type of processor(s) capable of performing the functions described herein. In particular, the processing device **202** may be embodied as one or more single or multi-core processors, microcontrollers, or other processor or processing/controlling circuits. For example, in some embodiments, the processing device **202** may include or be embodied as an arithmetic logic unit (ALU), central processing unit (CPU), digital signal processor (DSP), graphics processing unit (GPU), field-programmable gate array (FPGA), application-specific integrated circuit (ASIC), and/or another suitable processor(s). The processing device **202** may be a programmable type, a dedicated hardwired state machine, or a combination thereof. Processing devices **202** with multiple processing units may utilize distributed, pipelined, and/or parallel processing in various embodiments. Further, the processing device **202** may be dedicated to performance of just the operations described herein, or may be utilized in one or more additional applications. In the illustrative embodiment, the processing device **202** is programmable and executes algorithms and/or processes data in accordance with operating logic **208** as defined by programming instructions (such as software or firmware) stored in memory **206**. Additionally or alternatively, the operating logic **208** for processing device **202** may be at least partially defined by hardwired logic or other hardware. Further, the processing device **202** may include one or more components of any type suitable to process the signals received from input/output device **204** or from other components or devices and to provide desired output signals. Such components may include digital circuitry, analog circuitry, or a combination thereof.

**[0085]** The memory **206** may be of one or more types of non-transitory computer-readable media, such as a solid-state memory, electromagnetic memory, optical memory, or a combination thereof. Furthermore, the memory **206** may be volatile and/or nonvolatile and, in some embodiments, some or all of the memory **206** may be of a portable type, such as a disk, tape, memory stick, cartridge, and/or other suitable portable memory. In operation, the memory **206** may store various data and software used during operation of the computing device **200** such as operating systems, applications, programs, libraries, and drivers. It should be appreciated that the memory **206** may store data that is manipulated by the operating logic **208** of processing device **202**, such as, for example, data representative of signals received from and/or sent to the input/output device **204** in

addition to or in lieu of storing programming instructions defining operating logic **208**. As shown in FIG. **2**, the memory **206** may be included with the processing device **202** and/or coupled to the processing device **202** depending on the particular embodiment. For example, in some embodiments, the processing device **202**, the memory **206**, and/or other components of the computing device **200** may form a portion of a system-on-a-chip (SoC) and be incorporated on a single integrated circuit chip.

**[0086]** In some embodiments, various components of the computing device **200** (e.g., the processing device **202** and the memory **206**) may be communicatively coupled via an input/output subsystem, which may be embodied as circuitry and/or components to facilitate input/output operations with the processing device **202**, the memory **206**, and other components of the computing device **200**. For example, the input/output subsystem may be embodied as, or otherwise include, memory controller hubs, input/output control hubs, firmware devices, communication links (i.e., point-to-point links, bus links, wires, cables, light guides, printed circuit board traces, etc.) and/or other components and subsystems to facilitate the input/output operations.

**[0087]** The computing device **200** may include other or additional components, such as those commonly found in a typical computing device (e.g., various input/output devices and/or other components), in other embodiments. It should be further appreciated that one or more of the components of the computing device **200** described herein may be distributed across multiple computing devices. In other words, the techniques described herein may be employed by a computing system that includes one or more computing devices. Additionally, although only a single processing device **202**, I/O device **204**, and memory **206** are illustratively shown in FIG. **2**, it should be appreciated that a particular computing device **200** may include multiple processing devices **202**, I/O devices **204**, and/or memories **206** in other embodiments. Further, in some embodiments, more than one external device **210** may be in communication with the computing device **200**.

**[0088]** The computing device **200** may be one of a plurality of devices connected by a network or connected to other systems/resources via a network. The network may be embodied as any one or more types of communication networks that are capable of facilitating communication between the various devices communicatively connected via the network. As such, the network may include one or more networks, routers, switches, access points, hubs, computers, client devices, endpoints, nodes, and/or other intervening network devices. For example, the network may be embodied as or otherwise include one or more cellular networks, telephone networks, local or wide area networks, publicly available global networks (e.g., the Internet), ad hoc networks, short-range communication links, or a combination thereof. In some embodiments, the network may include a circuit-switched voice or data network, a packet-switched voice or data network, and/or any other network able to carry voice and/or data. In particular, in some embodiments, the network may include Internet Protocol (IP)-based and/or asynchronous transfer mode (ATM)-based networks. In some embodiments, the network may handle voice traffic (e.g., via a Voice over IP (VOIP) network), web traffic, and/or other network traffic depending on the particular embodiment and/or devices of the system in communication with one another. In various embodiments, the network may include analog or digital wired and wireless networks (e.g., IEEE 802.11 networks, Public Switched Telephone Network (PSTN), Integrated Services Digital Network (ISDN), and Digital Subscriber Line (xDSL)), Third Generation (3G) mobile telecommunications networks, Fourth Generation (4G) mobile telecommunications networks, Fifth Generation (5G) mobile telecommunications networks, a wired Ethernet network, a private network (e.g., such as an intranet), radio, television, cable, satellite, and/or any other delivery or tunneling mechanism for carrying data, or any appropriate combination of such networks. It should be appreciated that the various devices/systems may communicate with one another via different networks depending on the source and/or destination devices/systems.

**[0089]** It should be appreciated that the computing device **200** may communicate with other computing devices **200** via any type of gateway or tunneling protocol such as secure socket layer or transport layer security. The network interface may include a built-in network adapter, such as a network interface card, suitable for interfacing the computing device to any type of network capable of performing the operations described herein. Further, the network environment may be a virtual network environment where the various network components are virtualized. For example, the various machines may be virtual machines implemented as a software-based computer running on a physical machine. The virtual machines may share the same operating system, or, in other embodiments, different operating system may be run on each virtual machine instance. For example, a "hypervisor" type of virtualizing is used where multiple virtual machines run on the same host physical machine, each acting as if it has its own dedicated box. Other types of virtualization may be employed in other embodiments, such as, for example, the network (e.g., via software defined networking) or functions (e.g., via network functions virtualization).

**[0090]** Accordingly, one or more of the computing devices **200** described herein may be embodied as, or form a portion of, one or more cloud-based systems. In cloud-based embodiments, the cloud-based system may be embodied as a server-ambiguous computing solution, for example, that executes a plurality of instructions on-demand, contains logic to execute instructions only when prompted by a particular activity/trigger, and does not consume computing resources when not in use. That is, system may be embodied as a virtual computing environment residing "on" a computing system (e.g., a distributed network of devices) in which various virtual functions (e.g., Lambda functions, Azure functions, Google cloud functions, and/or other suitable virtual functions) may be executed corresponding with the functions of the system described herein. For example, when an event occurs (e.g., data is transferred to the system for handling), the virtual computing environment may be communicated with (e.g., via a request to an API of the virtual computing environment), whereby the API may route the request to the correct virtual function (e.g., a particular server-ambiguous computing resource) based on a set of rules. As such, when a request for the transmission of data is made by a user (e.g., via an appropriate user interface to the system), the appropriate virtual function(s) may be executed to perform the actions before eliminating the instance of the virtual function(s).

**[0091]** Referring now to FIG. **3**, in use, a computing system (e.g., the contact center system **100**, one or more

computing devices **200**, and/or other computing devices described herein) may execute a method **300** for filtering a trie data structure by a specific event. It should be appreciated that the particular blocks of the method **300** are illustrated by way of example, and such blocks may be combined or divided, added or removed, and/or reordered in whole or in part depending on the particular embodiment, unless stated to the contrary.

**[0092]** The illustrative method **300** begins with block **302** in which the computing system receives a trie for the entire data set for the organization. For example, as described above, the illustrative technologies may involve the creation of a single "big picture" trie that includes all of the bot flows (e.g., including relative attributes and/or other metadata) for the organization. For simplicity and brevity of the description, this trie may be referred to as a "mother trie" or a "big picture trie." This mother trie is able to be received by or otherwise accessed by the computing system (e.g., for filtering and querying). FIG. **6** illustrates an example trie in a state **600** in which it has been organized as a "big picture" mother trie (e.g., the state in which the trie is stored). In other embodiments, it should be appreciated that the mother trie may include a plurality of bot flows of the organization, but not necessarily all of the bot flows. For example, a particular organization may have an interest in partitioning its analyses and/or visualizations of bot flows and events.

**[0093]** As described above, FIG. **6** illustrates the initial state **600** of an example "big picture" mother trie after it has been created. The illustrative trie is a simple example created for an organization that includes three basic bot flows. For simplicity and clarity of the description, the possible event sequences or "journeys" are described in reference to "words." A first bot flow includes the journeys BALL (representing a sequence of the events B, A, L, and L), CAR (representing a sequence of the events C, A, and R), and A (representing a sequence including only the event A). A second bot flow includes the journeys BAT (representing a sequence of the events B, A, and T) and CART (representing a sequence of the events C, A, R, and T). A third bot flow includes the journeys CAT (representing a sequence of the events C, A, and T), A (representing a sequence including only the event A), XP (representing a sequence of the events X and P), and BLL (representing a sequence of the events B, L, and L). The same trie is also illustrated in state **1100** of FIG. **11**, which further illustrates the bot flow identifiers of the bot flows associated with each event adjacent the corresponding event.

**[0094]** In block **304**, the computing system receives a selection of a starting event of the trie by which to filter the trie. For example, as described above, an administrative user may visualize the trie in a graphical user interface and provide user input indicating that the user would like to filter the trie to include only events that include a particular starting event. In the illustrative embodiment of FIGS. **6-7**, the user has selected the event "a" to be the starting event. In block **306**, the computing system identifies each occurrence of the selected starting event in the trie. For example, as depicted in the state **602** of FIG. **6**, the computing system has identified each occurrence of the event "a" in the mother trie, which includes each of the events in the data set as described above. In some embodiments, in block **308**, the computing system may perform a depth first search in order to identify each occurrence of the selected starting event in the trie. In other embodiments, the computing system may utilize another search algorithm. In some embodiments, it should be appreciated that, in finding each occurrence of a particular starting event (e.g., the event "a" of the state **602** of FIG. **6**), the computing system may also identify each sub-trie that includes the selected event as the starting event (e.g., the three sub-tries highlighted in the state **602** of FIG. **6**).

**[0095]** If the computing system determines, in block **310**, that one or more occurrences of the selected event have been identified in the trie, the method **300** advances to block **312** in which the computing system extracts the sub-trie associated with each identified starting event. For example, as depicted in the state **700** of FIG. **7**, the computing system has extracted three sub-tries from the trie of state **602**, each of which sub-trie starts with the selected event "a." In block **314**, the computing system merges the extracted sub-tries to generate an updated trie. For example, as depicted in the state **702** of FIG. **7**, the computing system has merged the three illustrative sub-tries of state **700** into a single trie. It should be appreciated that the resultant updated trie satisfies the properties of a trie and, therefore, duplicative journeys are not present, for example. In block **316**, the computing system updates the event attributes of the merged and updated trie. For example, if an event in the merged trie was previously present in multiple sub-tries, the counts of the events from the sub-tries may be aggregated, and/or the other attributes may be aggregated or otherwise combined.

**[0096]** In block **318**, the computing system provides the updated trie to the administrative user. For example, in some embodiments, the updated trie may be returned to the requesting administrative user device for display on a graphical user interface, for visualization by the administrative user.

**[0097]** Although the blocks **302-318** are described in a relatively serial manner, it should be appreciated that various blocks of the method **300** may be performed in parallel in some embodiments.

**[0098]** Referring now to FIG. **4**, in use, a computing system (e.g., the contact center system **100**, one or more computing devices **200**, and/or other computing devices described herein) may execute a method **400** for filtering a trie data structure by an event attribute. It should be appreciated that the particular blocks of the method **400** are illustrated by way of example, and such blocks may be combined or divided, added or removed, and/or reordered in whole or in part depending on the particular embodiment, unless stated to the contrary.

**[0099]** The illustrative method **400** begins with block **402** in which the computing system receives a trie for the entire data set for the organization. For example, as described above, the illustrative technologies may involve the creation of a single "big picture" trie that includes all of the bot flows (e.g., including relative attributes and/or other metadata) for the organization (e.g., a "mother trie"). FIG. **8** illustrates an example trie in a state **800** in which it has been organized as a "big picture" mother trie (e.g., the state in which the trie is stored). The illustrative trie is a simple example created for an organization that includes the three basic bot flows described above. However, in the illustrative embodiment, each of the events includes an "animal" attribute, which includes possible values of at least "dog," "cat," and/or "hen." The attribute values associated with each event are illustrated in FIGS. **8-10** adjacent each corresponding event.

**[0100]** In block **404**, the computing system receives a selection of an event attribute of the trie by which to filter the trie or, more specifically, an event attribute value of the trie by which to filter the trie. For example, as described above, an administrative user may visualize the trie in a graphical user interface and provide user input indicating that the user would like to filter the trie to include only events that include a particular selected event attribute value. For example, in the illustrative embodiment of FIGS. **8-10**, the user has selected the "animal" attribute and, more specifically, the attribute value of "dog." In block **406**, the computing system identifies each event that does not include the selected event attribute or, more specifically, the selected event attribute value in the trie. For example, as depicted in the state **802** of FIG. **8**, the computing system has identified each event/node that does not include the attribute value "dog." That is, one event was identified as including the attribute value "cat," one event was identified as including the attribute value ["cat", "hen"], and another event was identified as including the attribute value "hen." In some embodiments, the computing system may perform a depth first search in order to identify each event in the trie that does not include the selected event attribute value. In other embodiments, the computing system may utilize another search algorithm.

**[0101]** If the computing system determines, in block **410**, that one or more events have been identified that does not included the selected event attribute value, the method **400** advances to block **412** in which the computing system deletes the identified events from the trie. In doing so, in block **414**, the computing system may update the parent-child relationships impacted by the deletion of the identified events. For example, the prior parent event/node of the deleted event may be temporarily connected (e.g., via a pointer) to the prior child events/nodes of the deleted event. As depicted in the state **900** of FIG. **9**, the computing system has deleted each of the identified events and created the temporary connections **902** to update the parent/child relationships impacted by the deletion of the events.

**[0102]** In block **416**, the computing system identifies each of the sub-tries of the parent events impacted by the deletion of the events. For example, in some embodiments, each prior parent event/node of a deleted event may be identified as the eldest parent node or root node of a sub-trie. For example, as depicted in the state **904** of FIG. **9**, the computing system has identified the sub-tries **906** based on the deleted events. In block **418**, the computing system merges the identified sub-tries (e.g., merges the events within each corresponding sub-trie) to generate an updated trie. For example, as depicted in the state **1000** of FIG. **10**, the computing system has merged the two illustrative sub-tries **906** of FIG. **9** to create a single trie. As described above, it should be appreciated that the resultant updated trie satisfies the properties of a trie and, therefore, duplicative journeys are not present, for example. In block **420**, the computing system updates the event attributes of the merged and updated trie. For example, if an event in the merged trie was previously present in multiple sub-tries, the counts of the events from the sub-tries may be aggregated, and/or the other attributes may be aggregated or otherwise combined.

**[0103]** In block **422**, the computing system provides the updated trie to the administrative user. For example, in some embodiments, the updated trie may be returned to the requesting administrative user device for display on a graphical user interface, for visualization by the administrative user.

**[0104]** Although the blocks **402-422** are described in a relatively serial manner, it should be appreciated that various blocks of the method **400** may be performed in parallel in some embodiments.

**[0105]** Referring now to FIG. **5**, in use, a computing system (e.g., the contact center system **100**, one or more computing devices **200**, and/or other computing devices described herein) may execute a method **500** for filtering a trie data structure by a bot flow. It should be appreciated that the particular blocks of the method **500** are illustrated by way of example, and such blocks may be combined or divided, added or removed, and/or reordered in whole or in part depending on the particular embodiment, unless stated to the contrary.

**[0106]** The illustrative method **500** begins with block **502** in which the computing system receives a trie for the entire data set for the organization. For example, as described above, the illustrative technologies may involve the creation of a single "big picture" trie that includes all of the bot flows (e.g., including relative attributes and/or other metadata) for the organization (e.g., a "mother" trie). FIG. **11** illustrates an example trie in a state **1100** in which it has been organized as a "big picture" mother trie (e.g., the state in which the trie is stored). As shown in FIG. **11**, the state **1100** also illustrates the bot flow identifiers (of bot flow 1, bot flow 2, and bot flow 3) associated with each event adjacent the corresponding event.

**[0107]** In block **504**, the computing system receives a selection of a bot flow of the trie by which to filter the trie. For example, as described above, an administrative user may visualize the trie in a graphical user interface and provide user input indicating that the user would like to filter the trie to include only events that are associated with a particular bot flow. In the illustrative embodiment of FIGS. **11-12**, the user has selected to filter the trie to include only events that are from bot flow 2. In block **506**, the computing system identifies each event that is not associated with the selected bot flow (e.g., based on associated bot flow identifiers stored as attributes in association with the events). For example, as depicted in the state **1102** of FIG. **11**, the computing system has identified each event/node that is not associated with bot flow 2. Those events associated with only bot flow 1 and/or bot flow 3 (and therefore not bot flow 2) have been highlighted for illustrative purposes. In some embodiments, the computing system may perform a depth first search in order to identify each event in the trie that is not associated with the selected bot flow. In other embodiments, the computing system may utilize another search algorithm.

**[0108]** If the computing system determines, in block **510**, that one or more events have been identified that are not associated with the selected bot flow, the method **500** advances to block **512** in which the computing system deletes the identified events from the trie. It should be appreciated that if a particular event/node is not associated with a particular bot flow, then none of its children will be associated with that particular bot flow as a matter of inherency. Accordingly, in some embodiments, during a depth first search, the computing system may identify an event/node that is not associated with the selected flow and delete the entire sub-trie of that node without further searching of that sub-trie, which makes the search more efficient.

As depicted in the state **1200** of FIG. **12**, the computing system has deleted each of the identified events to generate an updated trie. In block **514**, the computing system updates the event attributes of the updated trie. It should be appreciated that the deletion of non-selected bot flows may result in the frequency counts changing for events, and attributes may be updated as well as described above. For example, the event/node attributes of the state **1200** reflect the counts and/or other attributes from before deletion of the identified events, whereas the event/node attributes of the state **1202** reflect the updated counts and/or other attributes after deletion of the identified events. Additionally, it should be appreciated that bot flow 2 is the only bot flow identified as being associated with the remaining events.

**[0109]** In block **516**, the computing system provides the updated trie to the administrative user. For example, in some embodiments, the updated trie may be returned to the requesting administrative user device for display on a graphical user interface, for visualization by the administrative user.

**[0110]** Although the blocks **502-516** are described in a relatively serial manner, it should be appreciated that various blocks of the method **500** may be performed in parallel in some embodiments.

**[0111]** To support the generation of visualizations of trie data structures, a computing system (e.g., the contact center system **100**, one or more computing devices **200**, and/or other computing devices described herein) may perform operations to split the processing of a data frame (e.g., a data structure having rows and columns) of events associated with bot flows. In doing so, the computing system may partition a data frame into multiple partitions to be operated on by separate execution units (e.g., processing devices **202**), to produce corresponding trie data structures. The computing system may selectively merge trie data structures, such as those associated with the same organization, to produce a combined trie data structure indicative of events associated with bot flows related to that organization. As will be appreciated, the operations enable more efficient use of available processing capacity in the computing system, resulting in faster generation and manipulation of trie data structures. Further, the computing system may perform operations to accurately track data associated with nodes of a trie data structure represented in a visualization (e.g., in a user interface) as the visualization is manipulated (e.g., when a user selects a portion of the trie data structure for a drilled-down view).

**[0112]** Embodiments of the contact center system **100** enable path discovery, which is a type of journey management feature that provides an aggregate view into the most frequently occurring journeys of customers that affect bot containment (i.e., whether a customer escalates from interaction with an automated agent (a bot) to a human agent). Such an escalation may be indicative of a lack of ability of the automated agent to address the needs of the customer and may significantly influence the customer experience. Path discovery may be utilized in other domains relating to journey management that may involve different source datasets and/or the application of different algorithms or data structures. Accordingly, in the illustrative embodiment, flexibility is built into application programming interface (API) contracts associated with the domains. An API contract may be embodied as a technical specification that defines the rules and expectations for how an API should be used, including details such as endpoints, data formats, authentication methods, and the structures of requests and responses between components of a system that utilize the API. In at least some embodiments, path discovery operations do not require configuration and may be executed in a periodic (e.g., nightly) batch process to produce results for one or more organizations associated with the contact center system **100**. Accordingly, in at least some embodiments, the contact center system **100** provides a read-only endpoint as the primary API resource. That primary API resource, in at least some embodiments, provides path result sets and filtering capabilities to drill down to specific subsets of paths, such as drilling down from paths across all flows in an organization to paths for one specific flow, in accordance with the operations described above.

**[0113]** As will be appreciated from the description, a single path represents an aggregated sequence of customer journey events whereas a set of paths represents a collection of aggregated customer journey event sequences. Further, information about paths utilized by the contact center system **100**, in the illustrative embodiment, includes counts for each distinct branching path. That is, the count for a given distinct branching path represents the number of times customer(s) followed that particular path. In performing path discovery operations, the contact center system **100** determines paths from a given data set. Further, as used herein, a path domain represents a high-level container to group path discovery use cases. Within a given domain, the data structures and algorithms used are consistent. A path category, in the context of the contact center system **100** represents a set of paths that correspond to a specific use case or insight in a given path domain. Structurally, one path domain may contain multiple path categories. A path direction refers to the direction of the paths. Paths are typically unidirectional, in which the direction refers to whether the paths start at a particular event and diverge outwards or whether they converge at a particular end event. A path type, in the context of the contact center system **100**, specifies the data structure used to represent the corresponding path.

**[0114]** As will be appreciated, a trie data structure (also referred to herein as a "trie") is embodied as a tree data structure that aggregates the occurrence of specific unique sequences of nodes. Further, a trie data structure, which may also be referred to as a digital tree or prefix tree in computer science, is used to locate specific keys from within a set. Traditionally, tries are utilized in autocompletion use cases to predict the most likely, by frequency, word based on a given sequence of input characters. That is, in such use cases, each node may represent a character in a word. Referring back to the structure of a trie, the keys may be embodied as strings, with links between nodes defined not by the entire key, but by individual characters. In order to access a key (e.g., to recover the corresponding value, change the value, or remove the value), the trie is traversed depth-first, following the links between nodes that represent each character in the key. Unlike a binary search tree, nodes in the trie do not store their associated key. Rather, a node's position in the trie defines the key with which it is associated. Defining the key of a node based on that node's position in the trie causes the value of each key to be distributed across the trie data structure and means that node every node necessarily has an associated value. All of the children of a node have a common prefix of the string associated with the parent node, and the root is associated

with an empty string (i.e., the value of the root is an empty string). The task of storing data that can be accessed based on the prefix can be performed in a memory-efficient manner by employing a radix tree. A radix tree is a tree in which each node that is the only child is merged with its parent, thereby causing the number of children of every internal node to be, at most, the radix of the radix tree. Though tries can be keyed by character strings, they need not be. The same algorithms can be adapted for ordered lists of any underlying type, such as permutations of digits or shapes. A bitwise trie, in particular, is keyed on the individual bits making up a piece of fixed-length binary data, such as an integer or memory address. The key lookup complexity of a trie remains proportional to the key size. Specialized trie implementations, such as compressed tries are used to deal with the relatively large space requirement of a trie in naïve implementations.

**[0115]** In the context of path discovery for journey management use cases, for each path, a trie may represent a collection of journey event sequences. Further, a trie, in at least some embodiments, may be constructed from a set of six types of nodes. Each type of node represents important events on a customer journey and has corresponding unique characteristics. A root node is the starting point of the tree and is the only node without a parent node or a parent node identifier. An outcome node, in the illustrative embodiment, represents a flow outcome within a bot flow. The outcome node may be identified using a flowOutcomeId and flowOutcomeValue. The flowOutcomeValue represents whether the outcome represented by the outcome node was achieved (e.g., success or failure). A milestone node, in the illustrative embodiment, represents a flowMilestone within a bot flow. The milestone node may be identified using a flowMilestoneId and is associated with a flowOutcomeId. An error node may be embodied as a leaf node (i.e., a node with no children) and represents journey(s) that ended with a bot flow error. A transfer node may also be embodied as a leaf node (i.e., a node with no children) and represents the end of a customer journey, in which a customer was ultimately transferred from a bot (an automated agent) to a queue for a human agent. An escalation node may also be embodied as a leaf node and represents one or more journey(s) that ended with a customer expressly requesting (e.g., escalating) a transfer to a human agent queue, such as by stating "Can I speak to an agent?" An exit node may be embodied as a leaf node representing a normal termination of a flow execution.

**[0116]** Contact centers find customer journey data related to the way customers interact with contact center resources particularly useful for improving services and increasing efficiency. Pathway visualizations generated from such data are significant analytics tools that assist supervisors in managing resources and improving customer experiences, as such visualizations indicate the sequences of events that customers most often encounter as the customers navigate contact centers (e.g., when interacting with automated agent(s)). Some pathfinder applications, such as applications that are utilized to generate pathway visualizations, utilize trie data structures for efficient pathway calculations and related analytics. For example, some applications may utilize a library, such as the pygtrie library adapted for use with the Python programming language, to create and update trie data structures.

**[0117]** Within a given contact center, paths input data may be unevenly distributed across different organizations that utilize the contact center. Batch jobs may be grouped by organization identifiers and consolidated across all organization-specific data to individual executors (e.g., execution units). For relatively large organizations, the consolidation may result in data frames that are too large to be reliably read into memory and may cause faults if their size exceeds the available memory capacity. As described herein, in at least some embodiments, the contact center system **100** may perform operations to artificially increase the partition space with additional subpartitions under a given organization partition, and in doing so, address the reliability issue described above.

**[0118]** The contact center system **100** may partition an events data frame by organization identifier and sequence identifier. Preserving sequences of events is a significant factor in enabling processing of a corresponding trie data structure, as the sequence information indicates the path taken by a customer in their interactions with automated agents of the contact center system **100**. Repartitioning by organization and sequence identifiers enables events from the same sequence to be collocated in the same partition, while also causing data associated with the organization to be distributed across multiple data partitions, and hence, multiple executors (e.g., execution units). Doing so enables the processing load to be distributed more evenly than may otherwise be possible. As used herein, data partitioning refers to splitting data into multiple partitions (e.g., sets). For example, in at least some embodiments, the data is split into multiple Apache Spark partitions. As such, the contact center system **100** may execute transformations on multiple partitions pertaining to event data for an organization in parallel, allowing for more expedient (e.g., faster) completion of the batch jobs than may otherwise be possible. In some embodiments, the contact center system **100** may write partitioned data into a file system (e.g., multiple sub-directories) for faster reads by downstream systems.

**[0119]** In the illustrative embodiment, the contact center system **100** computes a trie for each data partition. Doing so produces a trie that represents the aggregate counts of a subset of all the unique event sequences in the corresponding organization. The contact center system **100** then saves the tries to a storage location, such as a temporary S3 storage location, in an efficient intermediate format (e.g., a Python pickle). Further, after the tries have been created and persisted (e.g., stored), the contact center system **100** may generate a data frame that represents unique organization identifiers and may partition that data frame by organization identifiers. That is, the contact center system **100** may partition the data frame to create one partition for each organization identifier. For each resulting partition, the contact center system **100** may iterate through a list of identified organization sub partitions and merge all corresponding tries for a given organization into one larger trie. The contact center system **100** may save the resulting merged trie in a defined output location (e.g., in an S3 location). Further, the contact center system **100** may perform category (e.g., path category) filtering, such as to identify escalations, transfers, or other events on that trie. The merge operation described above, which may occur on a single executor (e.g., execution unit) utilizes significantly less memory and is less computationally intensive than the initial event processing that occurs during the computation of paths. A more detailed description of the process is provided below, with reference to FIGS. **13-14**.

**[0120]** Referring now to FIG. **13**, in use, a computing system (e.g., the contact center system **100**, one or more computing devices **200**, and/or other computing devices described herein) may execute a method **1300** for partitioning data for efficient processing of trie data structures. It should be appreciated that the particular blocks of the method **1300** are illustrated by way of example, and such blocks may be combined or divided, added or removed, and/or reordered in whole or in part depending on the particular embodiment, unless stated to the contrary.

**[0121]** The illustrative method **1300** begins with block **1302** in which the computing system splits a data frame (e.g., a data structure having rows and columns) by organization identifiers and sequence identifiers to produce multiple corresponding partitions. Further, and as indicated in block **1304**, in the illustrative embodiment, the computing system splits a data frame that is representative of event associated with customer interactions with automated agents of a contact center. As described above, and as indicated in block **1306**, the computing system may assign each resulting partition to a separate execution unit (e.g., processing device **202**) to be processed in parallel.

**[0122]** Continuing the method **1300**, in block **1308**, the computing system, in the illustrative embodiment, produces a trie data structure for each partition that was produced in block **1302**. In doing so, in block **1310**, the computing system may produce trie data structures that each represents aggregate counts of a subset of all unique event sequences associated with a corresponding organization. Further, the computing system may iterate through each partition, as indicated in block **1312**. For each iteration, the computing system may generate groups of events that are based on the organization identifiers (e.g., each group of events is associated with a shared organization identifier), as indicated in block **1314**. Further, for each group, the computing system, in the illustrative embodiment, computes paths for event sequences represented in the group. In doing so, the computing system generates a corresponding subtrie data structure for the corresponding organization, as indicated in block **1316**. Further, the computing system stores each subtrie data structure in block **1318**.

**[0123]** Continuing the method **1300**, the computing system produces a combined organization trie data structure for each organization, in block **1320**. In doing so, the computing system identifies all unique organization identifiers in block **1322**. Further, the computing system repartitions the data frame based on the organization identifiers, as indicated in block **1324**. That is, the computing system produces one partition per organization identifier. In block **1326**, for each organization, the computing system merges the subtrie data structures associated with that organization. An embodiment of a method **1500** for merging the subtrie data structures is described with reference to FIG. **15**.

**[0124]** Continuing the method **1300** in block **1328** of FIG. **14**, the computing system stores the combined organization trie data structure for each organization. In doing so, the computing system may store the combined organization trie data structure in a format associated with an API contract, as indicated in block **1330**. That is, the computing system may store the trie data structure in a format according to a technical specification that defines a set of rules and expectations for how the API should be used, including details such as endpoints, data formats, authentication methods, and the structures of requests and responses between components of a system that utilize the API. In particular, the API relates to transmitting and receiving data pertaining to trie data structures, such as to support visualization of a given trie data structure in a user interface. Continuing the method **1300**, the computing system may perform filtering on the combined organization trie data structure for analytics, as indicated in block **1332**. For example, and as indicated in block **1334**, the computing system may perform filtering on the combined organization trie data structure based on one or more categories of paths associated with the organization (e.g., specific sequences of customer interactions with automated agents of the customer contact center **100** operating on behalf of the organization). Although the blocks **1302**-**1334** are described in a relatively serial manner, it should be appreciated that various blocks of the method **1300** may be performed in parallel in some embodiments.

**[0125]** Referring now to FIG. **15**, in use, a computing system (e.g., the contact center system **100**, one or more computing devices **200**, and/or other computing devices described herein) may execute a method **1500** for merging trie data structures into a combined trie data structure. It should be appreciated that the particular blocks of the method **1500** are illustrated by way of example, and such blocks may be combined or divided, added or removed, and/or reordered in whole or in part depending on the particular embodiment, unless stated to the contrary.

**[0126]** The illustrative method **1500** begins with block **1502** in which the computing system initializes an empty base trie data structure. Further, the computing system reads subtrie data structures from storage (e.g., S3 storage) in block **1504**. For example, the subtrie data structures may be the subtrie data structures generated in block **1316** of the method **1300**. Continuing the method **1500**, in block **1506**, the computing system merges each subtrie data structure in the base trie data structure that was initialized in block **1502**. In doing so, the computing system, in the illustrative embodiment, sorts node paths of the subtrie data structures based on distance from the root node, as indicated in block **1508**. Further, in the illustrative embodiment, the computing system sorts the node paths in ascending order (e.g., from smallest distance to largest distance). For example, if a trie has node paths: ROOT, ROOT/A, ROOT/A/B, ROOT/A/C, ROOT/D, the computing system may sort the node paths as: ROOT, ROOT/A, ROOT/D, ROOT/A/B, ROOT/A/C, based on distance from the root.

**[0127]** As indicated in block **1510**, for node paths (e.g., path from root to node) that exist in the base trie data structure already, the computing system combines the subtrie node with the base trie node. The combination includes merging and aggregation of flow counts for the two nodes that are being combined. Further, in the combination operation, the node identifier and the parent identifier of the base trie data structure take precedence. That is, the newly combined node has the node identifier and the parent identifier of the node in the base trie data structure, rather than that of the node from the subtrie that was merged into the base trie data structure.

**[0128]** Conversely, for node paths that do not presently exist in the base trie data structure, the computing system adds the corresponding subtrie node to the base trie data structure as a new node, as indicated in block **1512**. In doing so, in block **1514**, the computing system updates the parent identifier of the added node to the node identifier of the newly added node's parent node path in the base trie data

structure. In the illustrative embodiment, the parent node path will exist in the base trie data structure, as the nodes are merged from the subtrie in sorted order of distance from the root, as described above. As will be appreciated, updating the parent identifier of the newly added node ensures consistency with the remainder of the base subtrie data structure. In the illustrative embodiment, the method **1500** may be performed as a portion of the method **1300** described above, resulting in the combined organization trie data structure described above relative to blocks **1320**, **1328**, and **1332**. Although the blocks **1502-1514** are described in a relatively serial manner, it should be appreciated that various blocks of the method **1500** may be performed in parallel in some embodiments.

**[0129]** As briefly stated above, at least some embodiments of the contact center system **100** may perform operations to ensure that counts of inflow and outflow at each node in a trie data structure are accurate. That is, the contact center system **100** may perform operations to ensure that inflow and outflow counts at each node are equal in a visualization (e.g., a visual representation) of a set of paths associated with a trie data structure. In at least some embodiments, a user interface for providing such visualizations may utilize a recursive cycle function to group nodes having the same name, one node at a time, to produce a Sankey-like diagram.

**[0130]** In at least some embodiments, an issue may arise in which edge counts (e.g., relating to connections between nodes) are inaccurate. At a given node, the count at an input edge may be calculated as the total number of all output edges and all output edges of the child nodes, plus one. When the cycle function is executed, and nodes with the same name are merged, the context of only one node may be displayed in a user interface, rather than the context of all nodes that were combined. Accordingly, for a selected node for which counts are to be displayed, only the counts for that one selected node may be displayed, rather than a combined total count of all nodes that were merged into the node. To remedy the inaccurate count information, the contact center system **100** may execute a method **1600** described below.

**[0131]** Referring now to FIG. **16**, in use, a computing system (e.g., the contact center system **100**, one or more computing devices **200**, and/or other computing devices described herein) may execute a method **1600** for calculating accurate edge counts for a node associated with a trie data structure. It should be appreciated that the particular blocks of the method **1600** are illustrated by way of example, and such blocks may be combined or divided, added or removed, and/or reordered in whole or in part depending on the particular embodiment, unless stated to the contrary.

**[0132]** The illustrative method **1600** begins with block **1602** in which the computing system tracks merged nodes using a node map (e.g., a data structure that indicates nodes and relationships between the nodes). Further, in block **1604**, the computing system calculates an edge count for a selected node (e.g., in a user interface). In doing so, in block **1606**, the computing system may query the node map from block **1602** to identify a set of merged nodes that were merged into the selected node. Further, in block **1608**, the computing system sums individual counts associated with those merged nodes that were identified in block **1606**. In block **1610**, the computing system returns (e.g., to a process providing a visualization of the corresponding trie data structure, such as the combined organization tie data structure), the calculated edge count for the selected node.

**[0133]** Embodiments of the contact center system **100** may also perform specialized operations to support a drilled-down view of a portion of a trie data structure. That is, a visualization may enable a user to click on (e.g., select) a specific node for a drilled-down view (e.g., a focused view) pertaining to that node. In doing so, the contact center system **100** may show all paths leading up to the selected node (e.g., event). Further, the contact center system **100** removes, from the visualization, all paths that do not lead to the selected node and all nodes (e.g., events) that occur after the selected node. A problem related to the above functionality is that, while drilling down to a selected node, the edge counts for nodes may be recalculated using the cycle function referenced above, using a corresponding subset of data. However, given that the cycle function does not account for all nodes that were merged into the selected node, the contact center system **100** may calculate inaccurate count information for the selected node. As described with reference to FIG. **17**, the contact center system **100** may perform a method **1700** to update the counts of edges in the drilled-down view. To accurately calculate the counts for the drilled-down view, the contact center system **100** may utilize the node map described above with reference to the method **1600**. Although the blocks **1602-1610** are described in a relatively serial manner, it should be appreciated that various blocks of the method **1600** may be performed in parallel in some embodiments.

**[0134]** Referring now to FIG. **17**, in use, a computing system (e.g., the contact center system **100**, one or more computing devices **200**, and/or other computing devices described herein) may execute a method **1700** for calculating accurate count data for a drilled-down view in a visualization associated with a trie data structure. It should be appreciated that the particular blocks of the method **1700** are illustrated by way of example, and such blocks may be combined or divided, added or removed, and/or reordered in whole or in part depending on the particular embodiment, unless stated to the contrary.

**[0135]** The illustrative method **1700** begins with block **1702** in which the computing system identifies a selected node for a drilled-down view. Further, the computing system deletes child nodes of the selected node, in block **1704**. That is, the computing system removes, from the visualization, any data pertaining to child nodes of the selected node. Continuing the method **1700**, in block **1706**, the computing system identifies parent nodes (ancestors) of the selected node. In doing so, the computing system stores the identified parent nodes (ancestors) in a parent node set. Further, in block **1710**, the computing system identifies child nodes of the parent nodes in the parent node set from block **1706**. In block **1712**, the computing system subtracts counts of the identified child nodes from the counts of the corresponding parent nodes. Doing so provides an accurate representation of the subset of data pertaining to the drilled-down view. Further, the computing system deletes the identified child nodes, in block **1714**. That is, the computing system removes from the visualization, any representation of the child nodes. Additionally, in block **1716**, the computing system deletes (e.g., removes from the visualization) any previously unidentified nodes that do not pertain to the selected node (e.g., that do not lead to the selected node). Although the blocks **1702-1716** are described in a relatively

serial manner, it should be appreciated that various blocks of the method **1700** may be performed in parallel in some embodiments.

**[0136]** Referring to FIGS. **18** and **19**, a trie data structure **1800** in a first state, prior to the production of a drilled-down view, includes nodes **1802**, **1804**, **1806**, **1808**, **1810**, **1812**, **1814**, **1816**, **1818**. In response to a user selecting a particular node, which in the present example is the node **1810**, the computing system updates the state of the trie data structure **1800** as illustrated in FIG. **19** to support a drilled-down view. As indicated, only nodes **1802**, **1806**, **1810** along the path to the selected node **1810** are represented in the updated state, as each of the nodes **1804**, **1808**, **1812**, **1814**, **1816**, **1818** falls within one of the sets of nodes to be removed from the visualization in accordance with the method **1700**. That is, the node **1816** is removed for being a child of the selected node **1810**. Further, the nodes **1804**, **1808**, **1812**, **1814** are removed for being children of the set of parent nodes and that are not along the path to the selected node **1810**.

What is claimed is:

**1**. A method for providing efficient trie data structure processing, the method comprising:

splitting, by a computing system and based on organization identifiers and sequence identifiers, a data frame indicative of a set of events associated with customer interactions with automated agents of a contact center to produce a set of multiple partitions;

producing, by the computing system, a set of multiple trie data structures, including generating a trie data structure for each partition, wherein each trie data structure represents aggregate counts of a corresponding subset of event sequences associated with a corresponding organization;

merging, by the computing system, multiple trie data structures of the set of trie data structures to produce a combined organization trie data structure; and

storing, by the computing system, the combined organization trie data structure to enable generation of a visualization of the combined organization trie data structure.

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

assigning, by the computing system, each partition to a separate execution unit for concurrent processing.

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

performing, by the computing system, analytics on the combined organization trie data structure including filtering the combined organization trie data structure as a function of a path category indicative of a type of event that occurred during the customer interactions with the automated agents of the contact center.

**4**. The method of claim **1**, wherein merging the multiple trie data structures comprises:

identifying a set of unique organization identifiers associated with the multiple trie data structures;

repartitioning the data frame based on the organization identifiers; and

merging trie data structures that are associated with a shared organization identifier.

**5**. The method of claim **1**, wherein merging the multiple trie data structures comprises:

initializing an empty base trie data structure;

reading multiple trie data structures of the set from storage as subtrie data structures; and

merging each subtrie data structure into the base trie data structure.

**6**. The method of claim **5**, wherein merging each subtrie data structure into the base trie data structure comprises, for each subtrie data structure:

sorting node paths by distance from a root in ascending order; and

combining a subtrie node with a base trie node in response to a determination that a node path exists in the base trie data structure or adding the subtrie node to the base trie data structure as a new node in response to a determination that the node path does not exist in the base trie data structure.

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

tracking, by the computing system, merged nodes of the combined organization trie data structure using a node map; and

calculating, by the computing system, an edge count for a selected node represented in the node map, including querying the node map to identify the set of merged nodes and summing individual counts associated with the merged nodes.

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

identifying, by the computing system, a selected node of the combined organization trie data structure for a drilled-down view in the visualization;

identifying, by the computing system, a child node set of one or more child nodes of the selected node; and

deleting, by the computing system, the child node set from the visualization.

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

identifying a parent node set of one or more parent nodes of the selected node;

identifying a set of one or more child nodes of the parent node set;

subtracting counts of the identified child nodes from counts of corresponding parent nodes in the parent node set to provide an accurate representation of count data pertaining to the drilled-down view; and

deleting the identified child nodes of the parent node set in the drilled-down view.

**10**. A system for providing efficient trie data structure processing, the system comprising:

at least one processor; and

at least one memory comprising a plurality of instructions stored thereon that, in response to execution by the at least one processor, causes the system to:

split, based on organization identifiers and sequence identifiers, a data frame indicative of a set of events associated with customer interactions with automated agents of a contact center to produce a set of multiple partitions;

produce a set of multiple trie data structures, including generating a trie data structure for each partition, wherein each trie data structure represents aggregate counts of a corresponding subset of event sequences associated with a corresponding organization;

merge multiple trie data structures of the set of trie data structures to produce a combined organization trie data structure; and

store the combined organization trie data structure to enable generation of a visualization of the combined organization trie data structure.

**11**. The system of claim **10**, wherein the plurality of instructions further causes the system to assign each partition to a separate execution unit for concurrent processing.

**12**. The system of claim **10**, wherein the plurality of instructions further causes the system to perform analytics on the combined organization trie data structure including filtering the combined organization trie data structure as a function of a path category indicative of a type of event that occurred during the customer interactions with the automated agents of the contact center.

**13**. The system of claim **10**, wherein to merge the multiple trie data structures comprises to:

identify a set of unique organization identifiers associated with the multiple trie data structures;

repartition the data frame based on the organization identifiers; and

merge trie data structures that are associated with a shared organization identifier.

**14**. The system of claim **10**, wherein to merge the multiple trie data structures comprises to:

initialize an empty base trie data structure;

read multiple trie data structures of the set from storage as subtrie data structures; and

merge each subtrie data structure into the base trie data structure.

**15**. The system of claim **14**, wherein to merge each subtrie data structure into the base trie data structure comprises, for each subtrie data structure, to:

sort node paths by distance from a root in ascending order; and

combine a subtrie node with a base trie node in response to a determination that a node path exists in the base trie data structure or add the subtrie node to the base trie data structure as a new node in response to a determination that the node path does not exist in the base trie data structure.

**16**. The system of claim **10**, wherein the plurality of instructions further causes the system to:

track merged nodes of the combined organization trie data structure using a node map; and

calculate an edge count for a selected node represented in the node map, including querying the node map to identify the set of merged nodes and summing individual counts associated with the merged nodes.

**17**. The system of claim **10**, wherein the plurality of instructions further causes the system to:

identify a selected node of the combined organization trie data structure for a drilled-down view in the visualization;

identify a child node set of one or more child nodes of the selected node; and

delete the child node set from the visualization.

**18**. The system of claim **10**, wherein the plurality of instructions further causes the system to:

identify a parent node set of one or more parent nodes of the selected node;

identify a set of one or more child nodes of the parent node set;

subtract counts of the identified child nodes from counts of corresponding parent nodes in the parent node set to provide an accurate representation of count data pertaining to the drilled-down view; and

delete the identified child nodes of the parent node set in the drilled-down view.

**19**. One or more non-transitory machine-readable storage media comprising a plurality of instructions stored thereon that, in response to execution by a computing system, causes the computing system to:

split, based on organization identifiers and sequence identifiers, a data frame indicative of a set of events associated with customer interactions with automated agents of a contact center to produce a set of multiple partitions;

produce a set of multiple trie data structures, including generating a trie data structure for each partition, wherein each trie data structure represents aggregate counts of a corresponding subset of event sequences associated with a corresponding organization;

merge multiple trie data structures of the set of trie data structures to produce a combined organization trie data structure; and

store the combined organization trie data structure to enable generation of a visualization of the combined organization trie data structure.

**20**. The one or more non-transitory machine-readable storage media of claim **19**, wherein the plurality of instructions further causes the computing system to assign each partition to a separate execution unit for concurrent processing.

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