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Allocating shoppers for order fulfillment by an online concierge system accounting for variable numbers of shoppers across different time windows and varying capabilities for fulfilling orders

Abstract

An online concierge system maintains a data store with discrete time intervals for fulfilling orders and information on shoppers categorized in a tree structure based on their characteristics. When an order is received from a user's client device, the system employs a machine learning model trained on historical data to estimate the number of available shoppers and their corresponding levels in the tree structure. The order is tagged based on the items it contains, and these tags are matched to the levels of capable shoppers. Shoppers are grouped and scored based on their levels, and a group with the minimum score and capability to fulfill the order is selected. A shopper from this group is then dispatched for order fulfillment, leading to a decrement in the estimated number of shoppers in the selected group. This approach optimizes the allocation of shoppers to orders, ensuring efficient and timely fulfillment.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of co-pending U.S. application Ser. No. 17/308,996, filed May 5, 2021, which is incorporated by reference in its entirety.

BACKGROUND

(1) This disclosure relates generally to ordering items through an online concierge system, and more specifically to allocation of shoppers for fulfilling orders accounting for variable availability

of shoppers over time and varying capabilities for fulfilling orders.

(2) In current online concierge systems, shoppers (or “pickers”) fulfill orders at a physical warehouse, such as a retailer, on behalf of users as part of an online shopping concierge service. An online concierge system provides an interface to a user identifying items offered by a physical warehouse and receives selections of one or more items for an order from the user. In current online concierge systems, the shoppers may be sent to various warehouses with instructions to fulfill orders for items, and the shoppers then find the items included in the user order in a warehouse.

(3) Conventional online concierge systems maintain discrete time windows during which orders are fulfilled, and a user selects a specific time window for an order to be fulfilled by delivery to the user. For example, a user selects a time window corresponding to a specific range of times to schedule an order for fulfillment in the future or selects a time window that is an amount of time from a time when the order is placed for the order to be fulfilled as soon as possible. This allows users of an online concierge system to select a specific window for receiving items from an order or to obtain the items in an order within a specified time interval from a time when the order is placed.

(4) To fulfill orders received from users, the online concierge system estimates numbers of shoppers available for fulfilling orders during different time intervals and allocates a specific amount of the estimated number of shoppers as available to fulfill orders. The specific amount of the estimated shoppers available to fulfill orders during a time window is often less than the total number of estimated number of shoppers available to fulfill orders, allowing an online concierge system to maintain an amount of estimated shoppers for fulfilling orders within the specified time interval of times when the order is placed. While allocating a specific amount of an estimated number of shoppers for fulfilling orders scheduled for specific time windows allows the online concierge system to maintain resources to more rapidly fulfill short-term orders, significant increases in numbers of orders to be fulfilled occupies the specific amount or estimated shoppers available during multiple time windows, limiting time windows during which users may schedule orders for fulfillment.

(5) Additionally, certain orders have restrictions on fulfillment that limit their fulfillment to shoppers having certain characteristics (e.g., membership to a warehouse, authorization to purchase certain items, authorization to deliver certain items), limiting numbers of shoppers available for fulfilling those certain orders. Such restrictions on order fulfillment affect allocation of shoppers for fulfilling orders during different orders. For example, allocating a shopper having characteristics capable for fulfilling orders having one or more restrictions during a time interval to fulfill an order without restrictions prevents an online concierge system from subsequently fulfilling an order during the time interval having one or more of the restrictions, which may delay fulfillment of the order having the one or more restrictions. Conventional online concierge systems inefficiently account for restrictions for order fulfillment when allocating shoppers for fulfilling orders during time intervals, limiting their ability to fulfill received orders having one or more restrictions on fulfillment.

(6) Further, conventional online concierge systems hard-code restrictions for assigning shoppers to different orders, maintaining different rules for different restrictions. While this allows conventional online concierge systems to account for restrictions for characteristics of shoppers capable of fulfilling orders, such hard-coding of restrictions for shoppers capable of fulfilling orders is unable to efficiently account for changes in restrictions for shoppers capable of fulfilling orders. For example, adding restrictions for shoppers capable of fulfilling certain orders in conventional online systems involves creating and storing new-hard coded rules. Similarly, changing certain restrictions on fulfillment of orders may involve updating or modifying multiple hard-coded rules applying to different types of orders, increasing complexity and timing for such updates. Thus, such hard-coding rules for assigning shoppers to different orders is inefficient and poorly scalable as order requirements or shopper characteristics change, preventing conventional

online concierge systems from most efficiently implementing changes to characteristics of shoppers capable of fulfilling different orders.

SUMMARY

(7) An online concierge system maintains a plurality of discrete time intervals during which orders received by the online concierge system are fulfilled. For example, the online concierge system maintains multiple two-hour intervals during a day or another duration for fulfilling orders. This allows a user of the online concierge system to select a discrete time interval for an order provided by the user so that items included in the order are delivered to the user at a time within the selected discrete time interval. By selecting a discrete time interval, a user of the online concierge system can schedule delivery of items in the order at a future time within the selected discrete time interval, allowing the user to tailor when the order is fulfilled.

(8) From previously fulfilled orders, the online concierge system determines an estimated number of shoppers available to fulfill orders during each of at least a set of the discrete time intervals. For example, the online concierge system determines an estimated number of shoppers available to fulfill orders during each of the discrete time intervals. In various embodiments, the online concierge system applies a trained machine learned model to historical numbers of shoppers available to fulfill orders, or who fulfilled orders, at different discrete time intervals and characteristics of the discrete time interval (e.g., weekday or weekend, time of day, day of the week, day of the month, etc.), as well as a geographic location. To determine the estimated number of shoppers, the trained machine learned model receives a discrete time interval and a geographic location and determines the estimated number of shoppers available to fulfill orders during the discrete time interval based on historical numbers of shoppers available during prior time intervals corresponding to the discrete time interval, as well as the geographic location. The trained machine learned model for determining the estimated number of shoppers during a discrete time interval may be trained using any suitable method or combination of methods (e.g., supervised learning, unsupervised learning, semi-supervised learning, etc.). In various embodiments, the online concierge system determines an estimated number of shoppers available to fulfill orders during each discrete time interval of a set. For example, the set of discrete time intervals includes each discrete time interval within the maximum interval from a current time.

(9) The online concierge system receives an order from a user that includes one or more items for purchase, identifies a warehouse from which items of the order are to be obtained, and identifies a discrete time interval for fulfilling the order. Based on the warehouse and items in the order, fulfillment of the order may be limited to shoppers having one or more characteristics. For example, the order includes an item (e.g., alcohol, medication) for which a shopper is required to have a stored authorization or approval by the online concierge system to purchase or to deliver to a user. As another example, the order identifies a warehouse accessible to shoppers having a membership or affiliation with the warehouse to purchase items from the warehouse. In other embodiments, the online concierge system restricts fulfillment of orders to shoppers having any suitable characteristics or combinations of characteristics.

(10) From the items in the order and the warehouse identified by the order, the online concierge system applies one or more tags to the order. The tags applied to the order identify attributes of the order. The attributes of the order are determined from the warehouse specified by the order and items included in the order. The attributes of the order identify characteristics needed by a shopper to fulfill the order. Each tag corresponds to a different attribute of the order that identifies a characteristic of a shopper in some embodiments. Hence, for the online concierge system to select a shopper to fulfill the order, the shopper has characteristics satisfying the tags applied to the order. For example, if an order identifies a warehouse requiring a membership to be accessed, a tag applied to the order identifies the warehouse and the membership. As another example, if an order includes alcohol, a tag applied to the order indicates that a shopper be authorized by the online concierge system to purchase or to deliver alcohol. In another example, an order identifies a

warehouse requiring a membership to be accessed and includes alcohol, so the online concierge system applies a tag to the order indicating that the shopper be authorized by the online concierge system to purchase alcohol or to deliver alcohol and a tag identifying the warehouse and the membership to the warehouse. Hence, any number of tags may be applied to the order depending on the warehouse identified by the order and items included in the order.

(11) The online concierge system maintains a tree structure, or other hierarchical structure, for each tag, with the tree structure for a tag encoding capability of shoppers to fulfill orders to which a tag is applied. The tree structure hierarchically arranges characteristics of shoppers for fulfilling orders corresponding to the tag, with different levels of the tree structure corresponding to different characteristics of the shopper. In various embodiments, shoppers having characteristics in a level of the tree structure for a tag are capable of fulfilling orders that shoppers in a higher level of the tree structure are capable of fulfilling, but are unable to fulfill orders that shoppers in a lower level of the tree structure are capable of fulfilling. For example, a tree structure corresponding to membership in a warehouse includes a root level and a lower level for shoppers who are not members of the warehouse. An additional lower level is lower than the lower level and corresponds to shoppers who are members of the warehouse. In this example, shoppers who are members of the warehouse are capable of purchasing items from the warehouse and from warehouses that do not require a membership, while shoppers who are not members of the warehouse cannot purchase items from the warehouse. As another example, a tag corresponding to purchase of an item requiring authorization by the online concierge service to purchase or to deliver (e.g., alcohol or prescription medication) includes a root level and a lower level for shoppers who are not authorized by the online concierge system to purchase the specific item. An additional lower level is lower than the lower level and corresponds to shoppers who are authorized by the online concierge system to purchase or to deliver the specific item. In this example, a shopper who is authorized to purchase or to deliver the specific item (e.g., alcohol) is also capable of making purchases that shoppers who are not authorized to purchase or to deliver the specific item, while a shopper who is not authorized by the online concierge system to purchase or to deliver the specific item is unable to fulfill orders including the specific item. Each level in the hierarchy is also associated with a value, with lower levels in the tree structure having higher values in some embodiments, reflecting the ability of shoppers with characteristics in lower levels of the tree structure to also fulfill orders capable of being fulfilled by shoppers in higher levels of the tree structure. Thus, a higher value for a characteristic of a shopper indicates that a shopper with the characteristic is capable of fulfilling orders having a broader range of attributes.

(12) Maintaining the tree structures for different tags allows the online concierge system to more efficiently adjust capabilities of shoppers for fulfilling orders. For example, to add one or more characteristics to a tag, the online concierge system adds another characteristic to a level of the tree structure for the tag or adds an additional level to the tree structure for the tag, allowing the additional one or more characteristics to be considered without affecting the existing characteristics affecting fulfillment of orders associated with the tag. Similarly, the online concierge system is capable of more readily adjusting how a characteristic affects capability of a shopper for fulfilling orders. For example, the online concierge system increases or decreases a value of a level in a tree structure corresponding to a tag to adjust an effect of a characteristic corresponding to the level in shopper capability for fulfilling orders. In contrast to conventional techniques, where such changes would involve creation of new rules for shopper capabilities to fulfill orders, the tree structures can be readily modified, with the modified tree structures able to be quickly used for allocating shoppers to fulfill orders. Thus, the tree structures simplify modification of how characteristics of shoppers affect capability for fulfilling orders by allowing modification of one or more tree structures rather than reconfiguration of multiple hard-coded rules and relationships between characteristics corresponding to different hard-coded rules.

(13) The online concierge system determines one or more combinations of characteristics of

shoppers capable of fulfilling the order and accesses tree structures corresponding to each characteristic of shoppers included in at least one combination. For example, for an order identifying a warehouse that does not require a membership to access and does not include a specific item for which a shopper be authorized by the online concierge system to purchase or to deliver, the online concierge system determines that shoppers who are not members of a warehouse and shoppers who are members of a warehouse are capable of fulfilling the order and determines that shoppers who are authorized to purchase or to deliver the specific item by the online concierge system as well as shoppers who are not authorized to purchase or to deliver the specific item form the online concierge system are capable of fulfilling the order. In the preceding example, the online concierge system accesses a tree structure corresponding to membership in the warehouse and one or more tree structures for authorization by the online concierge system to purchase or to deliver one or more specific items. In another example, an order identifies a warehouse that requires a membership and a specific item requiring authorization by the online concierge system to purchase or to deliver, so the online concierge system determines that shoppers who are members of the warehouse and who are authorized by the online concierge system to purchase or to deliver the specific item are capable of fulfilling the order; thus, the online concierge system accesses a tree structure for membership in the warehouse and a tree structure for authorization by the online concierge system to purchase or to deliver the specific item.

(14) The tree structures corresponding to different tags allows the online concierge system to better account for combinations of characteristics of shoppers when allocating shoppers to fulfill an order. Conventional techniques for hard coding rules for allocating shoppers to orders are cumbersome and inefficient to implement to account for relative capabilities of shoppers with different characteristics to fulfill orders, with many conventional rules focusing on effect of a specific characteristic of a shopper in capability of the shopper fulfilling orders. The tree structures maintained by the online concierge system allow the online concierge system to more readily account for effects of multiple characteristics of a shopper on the shopper's capability to fulfill orders, providing a more efficient and accurate assessment of a shopper's capability for fulfilling various orders.

(15) Additionally, the online concierge system determines a number of estimated shoppers available to fulfill orders during the discrete time interval identified by the order from the estimated shoppers determined to be available to fulfill orders during the discrete time interval. The online concierge system includes each estimated shoppers available to fulfill orders during the discrete time interval into a group based on characteristics of each estimated shopper available to fulfill an order during the discrete time interval. Each group corresponds to a combination of characteristics of a shopper. For example, a group corresponds to a shopper being a member of a warehouse identified by the order and being authorized by the online concierge system to purchase or to deliver a specific item; another group corresponds to a shopper not being a member of the warehouse identified by the order and being authorized by the online concierge system to purchase or to deliver a specific item, while another group corresponds to a shopper being a member of the warehouse and not being authorized by the online concierge system to purchase or to deliver the specific item. Additionally, each group has a score based on the combination of characteristics corresponding to the group, with the score determined from values of levels in obtained tree structures corresponding to the tags applied to the order. In various embodiments, the online concierge system identifies a level in a tree structure for a tag applied to the order that includes characteristics of shoppers capable of fulfilling the order and retrieves a value corresponding to the identified level. The online concierge system combines values of levels in each tree structure corresponding to a tag applied to the order including a characteristics of shoppers in a group to determine the score for the group. For example, the score for a group is a product of values of levels in each tree structure corresponding to a tag applied to the order including a characteristics of shoppers in the group. However, in other embodiments, the online concierge system generates the score for a group by combining values of

levels in each tree structure corresponding to a tag applied to the order including a characteristics of shoppers in the group in any suitable manner in other embodiments.

(16) If the online concierge system modifies a tree structure the online concierge system, when the online concierge system subsequently generates an updated score for each group including a tag corresponding to the modified tree structure. The online concierge system uses the updated scores for the groups including the tag corresponding to the modified tree structure when selecting shoppers to fulfill orders associated with the tag. For example, the online concierge system adds one or more additional characteristics to the modified tree structure to identify other characteristics of the shopper capable of fulfilling the order including the tag by adding the additional characteristics to a level of the tree structure or by adding one or more levels to the tree structure. Similarly, the online concierge system may modify the tree structure by removing characteristics from one or more levels of the tree structure. In another example, the online concierge system increases or decreases a value of a level in the tree structure to reflect a change in capability of shoppers having characteristics corresponding to the level of the tree structure to fulfill orders. By generating scores for groups based on values of levels of tree structures corresponding to tags applied to the orders, the online concierge system is capable of quickly accounting for changes in order fulfillment for characteristics of shoppers through changes to the tree structures and using the modified scores for groups from the changes in the tree structures, reducing time and computational resources for the online concierge system to account for changes in characteristics of shoppers capable of fulfilling orders.

(17) The online concierge system identifies one or more groups having a combination of characteristics capable of fulfilling the order from the tags applied to the order and selects an estimated shopper from an identified group having a minimum score to fulfill the order. As shoppers with characteristics in lower levels of tree structures, which have higher values in the tree structures, are also capable of fulfilling orders that shoppers with characteristics in higher levels of tree structures are capable of fulfilling, the shoppers with characteristics in lower levels of tree structures are capable of fulfilling a wider range of orders. Hence, estimated shoppers in groups with higher scores are shoppers with a greater capability of fulfilling orders to which different tags or combinations of tags are applied. By selecting an estimated shopper from an identified group with a minimum score to fulfill the order, the online concierge system initially selects estimated shoppers with more limited capabilities to fulfill orders. This allows the online concierge system a greater flexibility in fulfilling subsequent orders by reserving estimated shoppers in groups with higher scores, corresponding to greater capabilities to fulfill orders, for subsequent selection to fulfill other orders.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

- (1) FIG. 1 illustrates an environment of an online shopping concierge service, according to one embodiment.
- (2) FIG. 2 is a diagram of an online shopping concierge system, according to one embodiment.
- (3) FIG. 3A is a diagram of a customer mobile application (CMA), according to one embodiment.
- (4) FIG. 3B is a diagram of a shopper mobile application (SMA), according to one embodiment.
- (5) FIG. 4 is a flowchart of a process for predicting inventory availability, according to one embodiment.
- (6) FIG. 5 is a flowchart of a method for selecting shoppers for fulfilling orders that accounts for restrictions of characteristics of shoppers capable of fulfilling received order, according to one embodiment.
- (7) FIG. 6 is an example of tree structures for tags corresponding to characteristics of users

maintained by an online concierge system, according to one embodiment.

(8) The figures depict embodiments of the present disclosure for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles, or benefits touted, of the disclosure described herein.

DETAILED DESCRIPTION

(9) System Overview

(10) FIG. 1 illustrates an environment **100** of an online platform, according to one embodiment. The figures use like reference numerals to identify like elements. A letter after a reference numeral, such as “**110a**,” indicates that the text refers specifically to the element having that particular reference numeral. A reference numeral in the text without a following letter, such as “**110**,” refers to any or all of the elements in the figures bearing that reference numeral. For example, “**110**” in the text refers to reference numerals “**110a**” and/or “**110b**” in the figures.

(11) The environment **100** includes an online concierge system **102**. The system **102** is configured to receive orders from one or more users **104** (only one is shown for the sake of simplicity). An order specifies a list of goods (items or products) to be delivered to the user **104**. The order also specifies the location to which the goods are to be delivered, and a time window during which the goods should be delivered. In some embodiments, the order specifies one or more retailers from which the selected items should be purchased. The user may use a customer mobile application (CMA) **106** to place the order; the CMA **106** is configured to communicate with the online concierge system **102**.

(12) The online concierge system **102** is configured to transmit orders received from users **104** to one or more shoppers **108**. A shopper **108** may be a contractor, employee, other person (or entity), robot, or other autonomous device enabled to fulfill orders received by the online concierge system **102**. The shopper **108** travels between a warehouse and a delivery location (e.g., the user's home or office). A shopper **108** may travel by car, truck, bicycle, scooter, foot, or other mode of transportation. In some embodiments, the delivery may be partially or fully automated, e.g., using a self-driving car. The environment **100** also includes three warehouses **110a**, **110b**, and **110c** (only three are shown for the sake of simplicity; the environment could include hundreds of warehouses). The warehouses **110** may be physical retailers, such as grocery stores, discount stores, department stores, etc., or non-public warehouses storing items that can be collected and delivered to users. Each shopper **108** fulfills an order received from the online concierge system **102** at one or more warehouses **110**, delivers the order to the user **104**, or performs both fulfillment and delivery. In one embodiment, shoppers **108** make use of a shopper mobile application **112** which is configured to interact with the online concierge system **102**.

(13) FIG. 2 is a diagram of an online concierge system **102**, according to one embodiment. The online concierge system **102** includes an inventory management engine **202**, which interacts with inventory systems associated with each warehouse **110**. In one embodiment, the inventory management engine **202** requests and receives inventory information maintained by the warehouse **110**. The inventory of each warehouse **110** is unique and may change over time. The inventory management engine **202** monitors changes in inventory for each participating warehouse **110**. The inventory management engine **202** is also configured to store inventory records in an inventory database **204**. The inventory database **204** may store information in separate records—one for each participating warehouse **110**—or may consolidate or combine inventory information into a unified record. Inventory information includes both qualitative and qualitative information about items, including size, color, weight, SKU, serial number, and so on. In one embodiment, the inventory database **204** also stores purchasing rules associated with each item, if they exist. For example, age-restricted items such as alcohol and tobacco are flagged accordingly in the inventory database **204**. Additional inventory information useful for predicting the availability of items may also be stored in the inventory database **204**. For example, for each item-warehouse combination (a particular

item at a particular warehouse), the inventory database **204** may store a time that the item was last found, a time that the item was last not found (a shopper looked for the item but could not find it), the rate at which the item is found, and the popularity of the item.

(14) Inventory information provided by the inventory management engine **202** may supplement the training datasets **220**. Inventory information provided by the inventory management engine **202** may not necessarily include information about the outcome of picking a delivery order associated with the item, whereas the data within the training datasets **220** is structured to include an outcome of picking a delivery order (e.g., if the item in an order was picked or not picked).

(15) The online concierge system **102** also includes an order fulfillment engine **206** which is configured to synthesize and display an ordering interface to each user **104** (for example, via the customer mobile application **106**). The order fulfillment engine **206** is also configured to access the inventory database **204** in order to determine which products are available at which warehouse **110**. The order fulfillment engine **206** may supplement the product availability information from the inventory database **204** with an item availability predicted by the machine-learned item availability model **216**. The order fulfillment engine **206** determines a sale price for each item ordered by a user **104**. Prices set by the order fulfillment engine **206** may or may not be identical to in-store prices determined by retailers (which is the price that users **104** and shoppers **108** would pay at the retail warehouses). The order fulfillment engine **206** also facilitates transactions associated with each order. In one embodiment, the order fulfillment engine **206** charges a payment instrument associated with a user **104** when he/she places an order. The order fulfillment engine **206** may transmit payment information to an external payment gateway or payment processor. The order fulfillment engine **206** stores payment and transactional information associated with each order in a transaction records database **208**.

(16) In some embodiments, the order fulfillment engine **206** also shares order details with warehouses **110**. For example, after successful fulfillment of an order, the order fulfillment engine **206** may transmit a summary of the order to the appropriate warehouses **110**. The summary may indicate the items purchased, the total value of the items, and in some cases, an identity of the shopper **108** and user **104** associated with the transaction. In one embodiment, the order fulfillment engine **206** pushes transaction and/or order details asynchronously to retailer systems. This may be accomplished via use of webhooks, which enable programmatic or system-driven transmission of information between web applications. In another embodiment, retailer systems may be configured to periodically poll the order fulfillment engine **206**, which provides detail of all orders which have been processed since the last request.

(17) The order fulfillment engine **206** may interact with a shopper management engine **210**, which manages communication with and utilization of shoppers **108**. In one embodiment, the shopper management engine **210** receives a new order from the order fulfillment engine **206**. The shopper management engine **210** identifies the appropriate warehouse **110** to fulfill the order based on one or more parameters, such as a probability of item availability determined by a machine-learned item availability model **216**, the contents of the order, the inventory of the warehouses, and the proximity to the delivery location. The shopper management engine **210** then identifies one or more appropriate shoppers **108** to fulfill the order based on one or more parameters, such as the shoppers' proximity to the appropriate warehouse **110** (and/or to the user **104**), his/her familiarity level with that particular warehouse **110**, and so on. Additionally, the shopper management engine **210** accesses a shopper database **212** which stores information describing each shopper **108**, such as his/her name, gender, rating, previous shopping history, and so on. Methods that can be used to identify a warehouse **110** at which a shopper **108** can likely find most or all items in an order are described with respect to FIG. 4.

(18) As part of fulfilling an order, the order fulfillment engine **206** and/or shopper management engine **210** may access a user database **214** which stores information describing each user. This information could include each user's name, address, gender, shopping preferences, favorite items,

stored payment instruments, and so on.

(19) In various embodiments, the order fulfillment engine **206** maintains discrete time intervals for fulfilling orders and a user identifies a discrete time interval in an order, allowing the user to specify a time window when items from the order are delivered to the user. Additionally, items included in orders or a warehouse **110** identified by certain orders limit shoppers capable of fulfilling the certain orders to shoppers having one or more characteristics. For example, an order identifying a warehouse **110** limiting purchases to shoppers who have a membership to the warehouse **110** is unable to be fulfilled by shoppers who are not members of the warehouse **110**. As another example, specific items (e.g. alcohol, prescription medication) in an order may be limited to being purchased by users who the online concierge system **102** authorizes to purchase the specific items, preventing an order including a specific item from being fulfilled by shoppers who are not authorized by the online concierge system **102** to purchase the specific item or to deliver the specific item. The order fulfillment engine **206** accounts for varying capabilities of shoppers with different characteristics to fulfill orders by applying one or more tags to a received order, where each tag corresponds to a different attribute of the order that identifies a characteristic of a shopper in some embodiments. Hence, for the online concierge system **102** to select a shopper to fulfill the order, the shopper has characteristics satisfying the tags applied **520** to the order.

(20) The order fulfillment engine **206** also maintains a tree structure for each tag, with the tree structure for a tag encoding capability of shoppers to fulfill orders to which a tag is applied. The tree structure hierarchically arranges characteristics of shoppers for fulfilling orders corresponding to the tag, with different levels of the tree structure corresponding to different characteristics of the shopper. In various embodiments, shoppers having characteristics in a level of the tree structure for a tag are capable of fulfilling orders that shoppers in a higher level of the tree structure are capable of fulfilling, but are unable to fulfill orders that shoppers in a lower level of the tree structure are capable of fulfilling. For example, a tree structure for a tag corresponding to alcohol includes a level for shoppers who are not authorized to purchase or to deliver alcohol and an additional, lower level for shoppers who are authorized to purchase or to deliver alcohol; in this example, a shopper who is authorized to purchase or to deliver alcohol is also capable of making non-alcohol purchases. Similarly, a tree structure for a tag corresponding to membership in a warehouse **110** includes a level for shoppers who are not members of the warehouse **110** and an additional, lower level for shoppers who are members of the warehouse **110**; in this example, shoppers who are members of the warehouse **110** are capable of purchasing items from the warehouse **110** and from warehouses **110** that do not require a membership, while shoppers who are not members of the warehouse **110** cannot purchase items from the warehouse **110**. Each level in the hierarchy is also associated with a value, with lower levels in the tree structure having higher values in some embodiments, reflecting the ability of shoppers with characteristics in lower levels of the tree structure to also fulfill orders capable of being fulfilled by shoppers in higher levels of the tree structure. By maintaining tree structures for different tags, the order fulfillment engine **206** is capable of more easily adding additional tags to reflect additional shopper characteristics affecting order fulfillment by maintaining one or more additional tree structures corresponding to the additional tags. Similarly, the tree structures may be more easily modified to reflect changes in shopper characteristics affecting shopper capability of fulfilling orders with different attributes. The tree structures for characteristics of shoppers for order fulfillment are further described below in conjunction with FIGS. 5 and 6.

(21) As further described below in conjunction with FIG. 5, the order fulfillment engine **206** accounts for characteristics of shoppers and tags identifying conditions for fulfilling orders identifying a discrete time interval when allocating shoppers to fulfill orders during discrete time intervals. The order fulfillment engine **206** leverages the tree structures for tags corresponding to orders to generate scores for various groups of estimated shoppers, where a group includes shoppers having one or more common characteristics, and selects estimated shoppers for a discrete

time interval from a group for fulfilling an order specifying the identified time interval. For example, the order fulfillment engine **206** selects an estimated shopper in a group having characteristics satisfying tags assigned with the order and having a lowest score of groups having a combination of characteristics capable of fulfilling the order.

(22) Machine Learning Models

(23) The online concierge system **102** further includes a machine-learned item availability model **216**, a modeling engine **218**, and training datasets **220**. The modeling engine **218** uses the training datasets **220** to generate the machine-learned item availability model **216**. The machine-learned item availability model **216** can learn from the training datasets **220**, rather than follow only explicitly programmed instructions. The inventory management engine **202**, order fulfillment engine **206**, and/or shopper management engine **210** can use the machine-learned item availability model **216** to determine a probability that an item is available at a warehouse **110**. The machine-learned item availability model **216** may be used to predict item availability for items being displayed to or selected by a user or included in received delivery orders. A single machine-learned item availability model **216** is used to predict the availability of any number of items.

(24) The machine-learned item availability model **216** can be configured to receive as inputs information about an item, the warehouse for picking the item, and the time for picking the item. The machine-learned item availability model **216** may be adapted to receive any information that the modeling engine **218** identifies as indicators of item availability. At minimum, the machine-learned item availability model **216** receives information about an item-warehouse pair, such as an item in a delivery order and a warehouse at which the order could be fulfilled. Items stored in the inventory database **204** may be identified by item identifiers. As described above, various characteristics, some of which are specific to the warehouse (e.g., a time that the item was last found in the warehouse, a time that the item was last not found in the warehouse, the rate at which the item is found, the popularity of the item) may be stored for each item in the inventory database **204**. Similarly, each warehouse may be identified by a warehouse identifier and stored in a warehouse database along with information about the warehouse. A particular item at a particular warehouse may be identified using an item identifier and a warehouse identifier. In other embodiments, the item identifier refers to a particular item at a particular warehouse, so that the same item at two different warehouses is associated with two different identifiers. For convenience, both of these options to identify an item at a warehouse are referred to herein as an “item-warehouse pair.” Based on the identifier(s), the online concierge system **102** can extract information about the item and/or warehouse from the inventory database **204** and/or warehouse database and provide this extracted information as inputs to the item availability model **216**.

(25) The machine-learned item availability model **216** contains a set of functions generated by the modeling engine **218** from the training datasets **220** that relate the item, warehouse, and timing information, and/or any other relevant inputs, to the probability that the item is available at a warehouse. Thus, for a given item-warehouse pair, the machine-learned item availability model **216** outputs a probability that the item is available at the warehouse. The machine-learned item availability model **216** constructs the relationship between the input item-warehouse pair, timing, and/or any other inputs and the availability probability (also referred to as “availability”) that is generic enough to apply to any number of different item-warehouse pairs. In some embodiments, the probability output by the machine-learned item availability model **216** includes a confidence score. The confidence score may be the error or uncertainty score of the output availability probability and may be calculated using any standard statistical error measurement. In some examples, the confidence score is based in part on whether the item-warehouse pair availability prediction was accurate for previous delivery orders (e.g., if the item was predicted to be available at the warehouse and not found by the shopper, or predicted to be unavailable but found by the shopper). In some examples, the confidence score is based in part on the age of the data for the item, e.g., if availability information has been received within the past hour, or the past day. The set

of functions of the item availability model **216** may be updated and adapted following retraining with new training datasets **220**. The machine-learned item availability model **216** may be any machine learning model, such as a neural network, boosted tree, gradient boosted tree or random forest model. In some examples, the machine-learned item availability model **216** is generated from XGBoost algorithm.

(26) The item probability generated by the machine-learned item availability model **216** may be used to determine instructions delivered to the user **104** and/or shopper **108**, as described in further detail below.

(27) The training datasets **220** relate a variety of different factors to known item availabilities from the outcomes of previous delivery orders (e.g. if an item was previously found or previously unavailable). The training datasets **220** include the items included in previous delivery orders, whether the items in the previous delivery orders were picked, warehouses associated with the previous delivery orders, and a variety of characteristics associated with each of the items (which may be obtained from the inventory database **204**). Each piece of data in the training datasets **220** includes the outcome of a previous delivery order (e.g., if the item was picked or not). The item characteristics may be determined by the machine-learned item availability model **216** to be statistically significant factors predictive of the item's availability. For different items, the item characteristics that are predictors of availability may be different. For example, an item type factor might be the best predictor of availability for dairy items, whereas a time of day may be the best predictive factor of availability for vegetables. For each item, the machine-learned item availability model **216** may weight these factors differently, where the weights are a result of a “learning” or training process on the training datasets **220**. The training datasets **220** are very large datasets taken across a wide cross section of warehouses, shoppers, items, warehouses, delivery orders, times and item characteristics. The training datasets **220** are large enough to provide a mapping from an item in an order to a probability that the item is available at a warehouse. In addition to previous delivery orders, the training datasets **220** may be supplemented by inventory information provided by the inventory management engine **202**. In some examples, the training datasets **220** are historic delivery order information used to train the machine-learned item availability model **216**, whereas the inventory information stored in the inventory database **204** include factors input into the machine-learned item availability model **216** to determine an item availability for an item in a newly received delivery order. In some examples, the modeling engine **218** may evaluate the training datasets **220** to compare a single item's availability across multiple warehouses to determine if an item is chronically unavailable. This may indicate that an item is no longer manufactured. The modeling engine **218** may query a warehouse **110** through the inventory management engine **202** for updated item information on these identified items.

(28) Additionally, the modeling engine **218** maintains a trained purchase model that receives inputs an identifier of the user, an identifier of an item, and a time. and outputs a probability of the user corresponding to the identifier of the user purchasing an item corresponding to the identifier of the item at the time. The trained purchase model accounts for times when the user previously purchased an item, such as a relative time from when the user previously purchased the item to a time when the model is applied, as well as characteristics of the item (e.g., a type of the item, a quantity or an amount of the item that was previously purchased). The trained purchase model may include a decay constant that decreases a weighting of purchases of the items over time, so purchases of the item at longer time intervals from the time when the trained purchase model is applied have lower weights than weights of purchases at the item at shorter time intervals from the time when the trained purchase model is applied. Additionally, the trained purchase model accounts for a frequency with which the user purchases an item, which increases a likelihood of the user purchasing an item if the user more frequently purchases the item. Other example factors used by the trained purchase model to determine the likelihood of a user purchasing an item include: a time interval between prior orders including the item received from the user, a frequency with which the

item is included in prior orders received from the user, times when orders including the item were previously received from the user. The trained purchase model may be trained using any suitable method or combination of methods (e.g., supervised learning, unsupervised learning, semi-supervised learning, etc.).

(29) Machine Learning Factors

(30) The training datasets **220** include a time associated with previous delivery orders. In some embodiments, the training datasets **220** include a time of day at which each previous delivery order was placed. Time of day may impact item availability, since during high-volume shopping times, items may become unavailable that are otherwise regularly stocked by warehouses. In addition, availability may be affected by restocking schedules, e.g., if a warehouse mainly restocks at night, item availability at the warehouse will tend to decrease over the course of the day. Additionally, or alternatively, the training datasets **220** include a day of the week previous delivery orders were placed. The day of the week may impact item availability, since popular shopping days may have reduced inventory of items or restocking shipments may be received on particular days. In some embodiments, training datasets **220** include a time interval since an item was previously picked in a previously delivery order. If an item has recently been picked at a warehouse, this may increase the probability that it is still available. If there has been a long time interval since an item has been picked, this may indicate that the probability that it is available for subsequent orders is low or uncertain. In some embodiments, training datasets **220** include a time interval since an item was not found in a previous delivery order. If there has been a short time interval since an item was not found, this may indicate that there is a low probability that the item is available in subsequent delivery orders. And conversely, if there is has been a long time interval since an item was not found, this may indicate that the item may have been restocked and is available for subsequent delivery orders. In some examples, training datasets **220** may also include a rate at which an item is typically found by a shopper at a warehouse, a number of days since inventory information about the item was last received from the inventory management engine **202**, a number of times an item was not found in a previous week, or any number of additional rate or time information. The relationships between this time information and item availability are determined by the modeling engine **218** training a machine learning model with the training datasets **220**, producing the machine-learned item availability model **216**.

(31) The training datasets **220** include item characteristics. In some examples, the item characteristics include a department associated with the item. For example, if the item is yogurt, it is associated with the dairy department. The department may be the bakery, beverage, nonfood and pharmacy, produce and floral, deli, prepared foods, meat, seafood, dairy, the meat department, or dairy department, or any other categorization of items used by the warehouse. The department associated with an item may affect item availability, since different departments have different item turnover rates and inventory levels. In some examples, the item characteristics include an aisle of the warehouse associated with the item. The aisle of the warehouse may affect item availability, since different aisles of a warehouse may be more frequently re-stocked than others. Additionally, or alternatively, the item characteristics include an item popularity score. The item popularity score for an item may be proportional to the number of delivery orders received that include the item. An alternative or additional item popularity score may be provided by a retailer through the inventory management engine **202**. In some examples, the item characteristics include a product type associated with the item. For example, if the item is a particular brand of a product, then the product type will be a generic description of the product type, such as “milk” or “eggs.” The product type may affect the item availability, since certain product types may have a higher turnover and re-stocking rate than others or may have larger inventories in the warehouses. In some examples, the item characteristics may include a number of times a shopper was instructed to keep looking for the item after he or she was initially unable to find the item, a total number of delivery orders received for the item, whether or not the product is organic, vegan, gluten free, or any other

characteristics associated with an item. The relationships between item characteristics and item availability are determined by the modeling engine **218** training a machine learning model with the training datasets **220**, producing the machine-learned item availability model **216**.

(32) The training datasets **220** may include additional item characteristics that affect the item availability and can therefore be used to build the machine-learned item availability model **216** relating the delivery order for an item to its predicted availability. The training datasets **220** may be periodically updated with recent previous delivery orders. The training datasets **220** may be updated with item availability information provided directly from shoppers **108**. Following updating of the training datasets **220**, a modeling engine **218** may retrain a model with the updated training datasets **220** and produce a new machine-learned item availability model **216**.

(33) Customer Mobile Application

(34) FIG. 3A is a diagram of the customer mobile application (CMA) **106**, according to one embodiment. The CMA **106** includes an ordering interface **302**, which provides an interactive interface with which the user **104** can browse through and select products and place an order. The CMA **106** also includes a system communication interface **304** which, among other functions, receives inventory information from the online shopping concierge system **102** and transmits order information to the system **102**. The CMA **106** also includes a preferences management interface **306** which allows the user **104** to manage basic information associated with his/her account, such as his/her home address and payment instruments. The preferences management interface **306** may also allow the user to manage other details such as his/her favorite or preferred warehouses **110**, preferred delivery times, special instructions for delivery, and so on.

(35) Shopper Mobile Application

(36) FIG. 3B is a diagram of the shopper mobile application (SMA) **112**, according to one embodiment. The SMA **112** includes a barcode scanning module **320** which allows a shopper **108** to scan an item at a warehouse **110** (such as a can of soup on the shelf at a grocery store). The barcode scanning module **320** may also include an interface which allows the shopper **108** to manually enter information describing an item (such as its serial number, SKU, quantity and/or weight) if a barcode is not available to be scanned. SMA **112** also includes a basket manager **322** which maintains a running record of items collected by the shopper **108** for purchase at a warehouse **110**. This running record of items is commonly known as a “basket”. In one embodiment, the barcode scanning module **320** transmits information describing each item (such as its cost, quantity, weight, etc.) to the basket manager **322**, which updates its basket accordingly. The SMA **112** also includes a system communication interface **324** which interacts with the online shopping concierge system **102**. For example, the system communication interface **324** receives an order from the system **102** and transmits the contents of a basket of items to the system **102**. The SMA **112** also includes an image encoder **326** which encodes the contents of a basket into an image. For example, the image encoder **326** may encode a basket of goods (with an identification of each item) into a QR code which can then be scanned by an employee of the warehouse **110** at check-out.

(37) Predicting Inventory Availability

(38) As described with reference to FIG. 2, the machine-learned item availability model **216** of the online concierge system **102** can determine an availability of an item requested by the user **104**. FIG. 4 is a flowchart illustrating a process **400** for predicting inventory availability, according to one embodiment. The online concierge system **102** receives **402** a delivery order that includes a set of items and a delivery location. The delivery location may be any location associated with a user, such as a user's home or office. The delivery location may be stored with the user location in the user database **214**. Based on the delivery order, the online concierge system **102** identifies a warehouse **404** for picking the set of items in the delivery order based on the set of items and the delivery location. In some cases, the user specifies a particular warehouse or set of warehouses (e.g., a particular grocery store or chain of grocery stores) in the order. In other cases, the online

concierge system **102** selects the warehouse based on the items and the delivery location. In some examples, there are a number of different possible warehouses that the set of items may be picked from. The warehouses may be identified by the order fulfillment engine **206** based on warehouses stored by the inventory management engine **202**, and warehouses are identified with a suitable inventory and within a threshold distance of the delivery address. In some embodiments, a single delivery order can be split into multiple orders and picked at multiple warehouses, e.g., if the items cannot be fulfilled at a single warehouse. In this example, each possible warehouse is input into the machine-learned item availability model **216**.

(39) After the warehouses are identified, the online concierge system **102** retrieves **406** the machine-learned item availability model **216** that predicts a probability that an item is available at the warehouse. The items in the delivery order and the identified warehouses are input into the machine-learned item availability model **216**. For example, the online concierge system **102** may input the item, warehouse, and timing characteristics for each item-warehouse pair into the machine-learned item availability model **216** to assess the availability of each item in the delivery order at each potential warehouse at a particular day and/or time. The machine-learned item availability model **216** predicts **408** the probability that one of the set of items in the delivery order is available at the warehouse. If a number of different warehouses are identified **404**, then the machine-learned item availability model **216** predicts the item availability for each one. In some examples, the probability that an item is available includes a probability confidence score generated by the machine-learned item availability model **216**.

(40) The order fulfillment engine **206** uses the probability to generate **410** an instruction to a shopper. The order fulfillment engine **206** transmits the instruction to the shopper through the SMA **112** via the shopper management engine **210**. The instruction is based on the predicted probability. In some examples, the shopper management engine **210** instructs the shopper to pick an item in the delivery order at a warehouse with the highest item availability score. For example, if a warehouse is more likely to have more items in the delivery order available than another warehouse, then the shopper management engine **210** instructs the shopper to pick the item at the warehouse with better availability. Other examples of the shopper management engine **210** instruction to the shopper are described in further detail with reference to FIGS. **5** and **6**. In some other examples, the order fulfillment engine **206** sends a message and/or instruction to a user based on the probability predicted by the machine-learned item availability model **216**.

(41) Selecting Shoppers for Fulfilling Orders Accounting for Restrictions in Shoppers Capable of Fulfilling Orders

(42) FIG. **5** is a flowchart of one embodiment of a method for selecting shoppers for fulfilling orders that accounts for restrictions of characteristics of shoppers capable of fulfilling received orders. In various embodiments, the method includes different or additional steps than those described in conjunction with FIG. **5**. Further, in some embodiments, the steps of the method may be performed in different orders than the order described in conjunction with FIG. **5**. The method described in conjunction with FIG. **5** may be carried out by the online concierge system **102** in various embodiments.

(43) An online concierge system **102** maintains **505** a plurality of discrete time intervals during which orders received by the online concierge system are fulfilled. For example, the online concierge system **102** maintains **505** multiple two hour intervals for fulfilling orders. As an example, the online concierge system **102** partitions a day into discrete two hour intervals for fulfilling orders. This allows a user of the online concierge system **102** to select a discrete time interval for an order provided by the user so items included in the order are delivered to the user at a time within the selected discrete time interval. By selecting a discrete time interval, a user of the online concierge system **102** is able to schedule delivery of items in the order at a future time within the selected discrete time interval, allowing the user to tailor when the order is fulfilled. In some embodiments, the online concierge system **102** maintains a maximum interval and allows a

user to select a discrete time interval that is within the maximum interval from a time when the order is received by the online concierge system **102** to limit how long in the future the user may schedule fulfillment of the order.

(44) From previously fulfilled orders, the online concierge system **102** determines **510** an estimated number of shoppers available to fulfill orders during each of at least a set of the discrete time intervals. For example, the online concierge system **102** determines **510** an estimated number of shoppers available to fulfill orders during each of the discrete time intervals. In various embodiments, the online concierge system **102** applies a trained machine learned model to historical numbers of shoppers available to fulfill orders, or who fulfilled orders, at different discrete time intervals and characteristics of the discrete time interval (e.g., weekday or weekend, time of day, day of the week, day of the month, etc.), as well as a geographic location. To determine **510** the estimated number of shoppers, the trained machine learned model receives a discrete time interval and a geographic location and determines **510** the estimated number of shoppers available to fulfill orders during the discrete time interval based on historical numbers of shoppers available during prior time intervals corresponding to the discrete time interval, as well as the geographic location. The trained machine learned model for determining **510** the estimated number of shoppers during a discrete time interval may be trained using any suitable method or combination of methods (e.g., supervised learning, unsupervised learning, semi-supervised learning, etc.). In various embodiments, the online concierge system **102** determines **510** an estimated number of shoppers available to fulfill orders during each discrete time interval of a set. For example, the set of discrete time intervals includes each discrete time interval within the maximum interval from a current time.

(45) In some embodiments, the online concierge system **102** maintains a specified percentage of shoppers to allocate per discrete time interval for fulfilling orders. Based on the specified percentage, the online concierge system **102** allocates the specified percentage of estimated shoppers for a discrete time interval for fulfilling orders specifying the discrete time interval. The specified percentage of estimated shoppers for a discrete time interval for fulfilling orders specifying the discrete time interval is less than 100%, with the remaining percentage of the estimated shoppers for the discrete time interval are allocated by the online concierge system **102** for fulfilling orders received during the discrete time interval and indicating short term fulfillment (i.e., fulfillment within a threshold amount of time from a time when the order was received). This allocation allows the online concierge system **102** to divide the number of estimated shoppers during the discrete time interval between orders received before the discrete time interval that specify fulfillment during the discrete time interval and orders received during the discrete time interval identifying short term fulfillment for fulfillment. In some embodiments, the specified percentage is constant for different discrete time intervals. For example, the specified percentage is 70%, so the online concierge system **102** allocates 70% of the estimated number of shoppers for the discrete time interval to fulfill orders received before the discrete time interval that specify fulfillment during the discrete time interval and allocates 30% of the estimated number of shoppers for the discrete time interval to fulfill orders indicating short term fulfillment and received during the discrete time interval. In other embodiments, the online concierge system **102** maintains different specified percentage for different discrete time intervals; for example, the online concierge system **102** maintains a specified percentage for discrete time intervals occurring within a portion of a day (e.g., a morning) and a different specified percentage for discrete time intervals occurring within a different portion of the day (e.g., an afternoon).

(46) The online concierge system **102** receives **515** an order from a user that includes one or more items for purchase, identifies a warehouse **110** from which items of the order are to be obtained, and identifies a discrete time interval for fulfilling the order. Based on the warehouse **110** and items in the order, fulfillment of the order may be limited to shoppers having one or more characteristics. For example, the order includes an item (e.g., alcohol, medication) for which a shopper is required

to have a stored authorization or approval by the online concierge system **102** to purchase or to deliver (also referred to as authorization or approval by the online concierge system **102** to “obtain” the item). As another example, the order identifies a warehouse **110** accessible to shoppers having a membership or affiliation with the warehouse **110** to purchase items from the warehouse **110**. In other embodiments, the online concierge system **102** restricts fulfillment of orders to shoppers having any suitable characteristics or combinations of characteristics. Hence, the restriction on fulfilling an order encompasses a restriction on shoppers capable of purchasing a product from a warehouse **110** or a restriction on shoppers capable of delivering an item from a warehouse **110** to a location specified by an order.

(47) From the items in the order and the warehouse identified by the order, the online concierge system **102** applies **520** one or more tags to the order. The tags applied **520** to the order identify attributes of the order. The attributes of the order are determined from the warehouse **110** specified by the order and items included in the order. The attributes of the order identify characteristics needed by a shopper to fulfill the order. Each tag corresponds to a different attribute of the order that identifies a characteristic of a shopper in some embodiments. Hence, for the online concierge system **102** to select a shopper to fulfill the order, the shopper has characteristics satisfying the tags applied **520** to the order. For example, if an order identifies a warehouse **110** requiring a membership to be accessed, a tag applied **520** to the order identifies the warehouse **110** and the membership. As another example, if an order includes alcohol, a tag applied **520** to the order indicates that a shopper be authorized by the online concierge system **102** to purchase alcohol or to deliver alcohol from a warehouse **110**. In another example, an order identifies a warehouse **110** requiring a membership to be accessed and includes alcohol, so the online concierge system **102** applies **520** a tag to the order indicating that the shopper be authorized by the online concierge system **102** to purchase alcohol (or to deliver alcohol) and a tag identifying the warehouse **110** and the membership to the warehouse **110**. Hence, any number of tags may be applied **520** to the order depending on the warehouse **110** identified by the order and items included in the order.

(48) The online concierge system **102** maintains a tree structure for each tag, with the tree structure for a tag encoding capability of shoppers to fulfill orders to which a tag is applied. The tree structure hierarchically arranges characteristics of shoppers for fulfilling orders corresponding to the tag, with different levels of the tree structure corresponding to different characteristics of the shopper. In various embodiments, shoppers having characteristics in a level of the tree structure for a tag are capable of fulfilling orders that shoppers in a higher level of the tree structure are capable of fulfilling, but are unable to fulfill orders that shoppers in a lower level of the tree structure are capable of fulfilling. FIG. 6 shows example tree structures for tags corresponding to characteristics of shoppers. Tree structure **600** in FIG. 6 corresponds to membership in a warehouse **110**. Tree structure **600** includes a root level **602** and a lower level **604** for shoppers who are not members of the warehouse **110**. An additional lower level **606** is lower than the lower level **604** and corresponds to shoppers who are members of the warehouse **110**. In this example, shoppers who are members of the warehouse **110**, corresponding to the additional lower level **606**, are capable of purchasing items from the warehouse **110** and from warehouses **110** that do not require a membership (so a shopper included in the additional lower level **606** is capable of fulfilling orders that a shopper in the lower level **604** can fulfill), while shoppers who are not members of the warehouse **110**, and are included in lower level **604**, cannot purchase items from the warehouse **110** that shoppers in additional lower level **606** can fulfill. FIG. 6 also shows an example tree structure **610** tree structure for a tag corresponding to purchase or delivery of an item requiring authorization by the online concierge service to purchase or to deliver (e.g., alcohol or prescription medication). Tree structure **610** includes a root level **612** and a lower level **614** for shoppers who are not authorized by the online concierge system **102** to purchase or to deliver the specific item. An additional lower level **616** is lower than the lower level **614** and corresponds to shoppers who are authorized by the online concierge system **102** to purchase or to deliver the specific item. In this

example, a shopper who is authorized to purchase or to deliver the specific item (e.g., alcohol) and is in the additional lower level **616** is also capable of making purchases or deliveries that shoppers who are not authorized to purchase or to deliver the specific item and are in the lower level **614** can make; however, a shopper in the lower level **614** is not capable of fulfilling an order including the specific item, while a shopper in the additional lower level **616** can fulfill such an order. While FIG. 6 depicts a tree structure, in other embodiments, the online concierge system **102** maintains any suitable hierarchical data structure identifying different characteristics of shoppers affecting ability of shoppers to fulfill orders.

(49) Maintaining the tree structures for different tags allows the online concierge system **102** to more efficiently adjust capabilities of shoppers for fulfilling orders. For example, to add one or more characteristics to a tag, the online concierge system **102** adds another characteristic to a level of the tree structure for the tag or adds an additional level to the tree structure for the tag, allowing consideration of the additional one or more characteristics when allocating shoppers to fulfill orders without affecting the existing characteristics affecting fulfillment of orders associated with the tag. Similarly, the tree structures allow the online concierge system **102** to more readily adjust how a characteristic affects capability of a shopper for fulfilling orders. For example, the online concierge system **102** increases or decreases a value of a level in a tree structure corresponding to a tag or moves a characteristic to a different level in the tree structure to adjust an effect of the characteristic in shopper capability for fulfilling orders. In conventional techniques such changes would involve creation of new rules for shopper capabilities to fulfill orders and corresponding adjustments to existing rules to reflect the changed effect of a characteristic of the shopper, the tree structures can be readily modified, with the modified tree structures able to be quickly used for allocating shoppers to fulfill orders, as further described below.

(50) Referring back to FIG. 5, each level in the hierarchy is also associated with a value, with lower levels in the tree structure having higher values in some embodiments, reflecting the ability of shoppers with characteristics in lower levels of the tree structure to also fulfill orders capable of being fulfilled by shoppers in higher levels of the tree structure. In the example of FIG. 6, root level **602** and root level **612** each have a value of 1, while lower level **604** and lower level **614** each have a value of 2. Further, additional lower level **606** and additional lower level **616** each have a value of 3. In other hierarchical structures, levels corresponding to characteristics of shoppers capable of fulfilling a greater number of orders have higher values. Thus, a higher value for a characteristic of a shopper indicates that a shopper with the characteristic is capable of fulfilling orders having a broader range of attributes.

(51) Again referring to FIG. 5, the online concierge system **102** determines **525** one or more combinations of characteristics of shoppers capable of fulfilling the order and accesses **530** tree structures corresponding to each characteristic of shoppers included in at least one combination. For example, for an order identifying a warehouse **110** that does not require a membership to access and does not include a specific item for which a shopper be authorized by the online concierge system **102** to purchase or to deliver, the online concierge system **102** determines **525** that shoppers who are not members of a warehouse **110** and shoppers who are members of a warehouse **110** are capable of fulfilling the order and determines **525** that shoppers who are authorized to purchase or to deliver the specific item by the online concierge system **102** as well as shoppers who are not authorized to purchase or to deliver the specific item from the online concierge system **102** are capable of fulfilling the order. In the preceding example, the online concierge system **102** accesses **530** a tree structure corresponding to membership in the warehouse **110** and one or more tree structures for authorization by the online concierge system **102** to purchase or to deliver one or more specific items. In another example, an order identifies a warehouse **110** that requires a membership and a specific item requiring authorization by the online concierge system **102** to purchase or to deliver, so the online concierge system **102** determines **525** that shoppers who are members of the warehouse **110** and who are authorized by the online

concierge system **102** to purchase or to deliver the specific item are capable of fulfilling the order; thus, the online concierge system **102** accesses **530** a tree structure for membership in the warehouse **110** and a tree structure for authorization by the online concierge system **102** to purchase the specific item.

(52) The tree structures corresponding to different tags allows the online concierge system **102** to better account for combinations of characteristics of shoppers when allocating shoppers to fulfill an order. Conventional techniques that hard code rules for allocating shoppers to orders are cumbersome and inefficient to implement to account for relative capabilities of shoppers with different characteristics to fulfill orders, with many conventional rules focusing on effects of a specific characteristic of a shopper in capability of the shopper fulfilling orders without accounting for effects of a combination of multiple characteristics of a shopper affecting orders capable of being fulfilled by the shopper. The tree structures maintained by the online concierge system **102** allow the online concierge system **102** to more readily account for effects of multiple characteristics of a shopper on the shopper's capability to fulfill orders, providing a more efficient and accurate assessment of a shopper's capability for fulfilling various orders.

(53) Additionally, the online concierge system **102** determines **535** a number of estimated shoppers available to fulfill orders during the discrete time interval identified by the order from the estimated shoppers determined **510** to be available to fulfill orders during the discrete time interval. The online concierge system **102** includes **540** each estimated shoppers available to fulfill orders during the discrete time interval into a group based on characteristics of each estimated shopper available to fulfill an order during the discrete time interval. Each group corresponds to a combination of characteristics of a shopper. For example, a group corresponds to a shopper being a member of a warehouse **110** identified by the order and being authorized by the online concierge system **102** to purchase or to deliver a specific item; another group corresponds to a shopper not being a member of the warehouse **110** identified by the order and being authorized by the online concierge system **102** to purchase or to deliver a specific item, while another group corresponds to a shopper being a member of the warehouse **110** and not being authorized by the online concierge system **102** to purchase or to deliver the specific item. Additionally, each group has a score based on the combination of characteristics corresponding to the group, with the score determined from values of levels in obtained tree structures corresponding to the tags applied **520** to the order. In various embodiments, the online concierge system **102** identifies a level in a tree structure for a tag applied **520** to the order that includes characteristics of shoppers capable of fulfilling the order and retrieves a value corresponding to the identified level. The online concierge system **102** combines values of levels in each tree structure corresponding to a tag applied to the order **520** including a characteristics of shoppers in a group to determine the score for the group. For example, the score for a group is a product of values of levels in each tree structure corresponding to a tag applied to the order **520** including a characteristics of shoppers in the group. However, in other embodiments, the online concierge system **102** generates the score for a group by combining values of levels in each tree structure corresponding to a tag applied to the order **520** including a characteristics of shoppers in the group in any suitable manner in other embodiments.

(54) If the online concierge system **102** modifies a tree structure the online concierge system, when the online concierge system **102** subsequently generates an updated score for each group including a tag corresponding to the modified tree structure. The online concierge system **102** uses the updated scores for the groups including the tag corresponding to the modified tree structure when selecting shoppers to fulfill orders associated with the tag, as further described below. For example, the online concierge system **102** adds one or more additional characteristics to the modified tree structure to identify other characteristics of the shopper capable of fulfilling the order including the tag by adding the additional characteristics to a level of the tree structure or by adding one or more levels to the tree structure. Similarly, the online concierge system **102** may modify the tree structure by removing characteristics from one or more levels of the tree structure. In another example, the

online concierge system **102** increases or decreases a value of a level in the tree structure to reflect a change in capability of shoppers having characteristics corresponding to the level of the tree structure to fulfill orders. By generating scores for groups based on values of levels of tree structures corresponding to tags applied to the orders, the online concierge system is capable of quickly accounting for changes in order fulfillment for characteristics of shoppers through a modified tree structure for a tag to create a modified score for a group including the tag from the modified tree structure and using the modified score for the group when selecting estimated shoppers to fulfill a subsequently received order, reducing time and computational resources for the online concierge system **102** to account for changes in characteristics of shoppers capable of fulfilling orders. This increased scalability and adaptability allows the online concierge system **102** to more efficiently allocate computational resources and time to adjust or alter how characteristics of shoppers affect capability of the shopper to fulfill orders with various tags.

(55) The online concierge system **102** identifies **540** one or more groups having a combination of characteristics capable of fulfilling the order from the tags applied to the order and selects **550** an estimated shopper from an identified group having a minimum score to fulfill the order. As shoppers with characteristics in lower levels of tree structures, which have higher values in the tree structures, are also capable of fulfilling orders that shoppers with characteristics in higher levels of tree structures are capable of fulfilling, the shoppers with characteristics in lower levels of tree structures are capable of fulfilling a wider range of orders. Hence, estimated shoppers in groups with higher scores are shoppers with a greater capability of fulfilling orders to which different tags or combinations of tags are applied **520**. For example, referring to the example in FIG. 6, a group corresponding to shoppers who are members of a warehouse **110** and who are authorized by the online concierge system **102** to purchase or to deliver the specific item has a score of 9, which is a product of 3, the value for the additional lower level **606**, and 3, the value for the additional lower level **616**; similarly, a group corresponding to shoppers who are not members of a warehouse **110** and who are authorized to purchase or to deliver the specific item has a score of 6, which is a product of 2, the value for the lower level **605**, and 3, the value of the additional lower level **616**. Hence, by selecting **550** an estimated shopper from an identified group with a minimum score to fulfill the order, the online concierge system **102** initially selects **550** estimated shoppers with more limited capabilities to fulfill orders. This allows the online concierge system **102** a greater flexibility in fulfilling subsequent orders by reserving estimated shoppers in groups with higher scores, corresponding to greater capabilities to fulfill orders, for subsequent selection to fulfill other orders.

(56) In response to selecting **550** the estimated shopper from the identified group having the minimum score to fulfill the order, the online concierge system **102** decrements **555** the number of estimated shoppers in the identified group. This allows the online concierge system **102** to account for the reduced number of estimated shoppers in the identified group when selecting shoppers for fulfilling other orders. By decrementing **555** the number of estimated shoppers in the identified group for the discrete time interval from the order, the online concierge system **102** more accurately identifies discrete time intervals during which orders may be fulfilled by accounting for estimated numbers of shoppers with characteristics capable of fulfilling orders with different attributes during different discrete time intervals rather than an overall number of estimated number of shoppers available during the different discrete time intervals. As further described above, the tree structures maintained by the online concierge system **102** for various tags allow the online concierge system **102** to more efficiently and accurately account for combinations of characteristics of shoppers affecting capabilities of the shoppers to fulfill various orders. This increased accuracy in identifying estimated shoppers capable of fulfilling orders reduces a likelihood of a user receiving an order late or selecting an order for fulfillment during a time interval when there are not shoppers having characteristics capable of fulfilling the order.

(57) In some embodiments, the online concierge system **102** determines estimated numbers of

shoppers for the discrete time interval specified by the order in each group capable of fulfilling orders having tags associated with the received order when the order is received **515**. In response to determining that each group capable of fulfilling orders having tags associated with the received order includes less than a threshold number of shoppers during the discrete time interval, the online concierge system **102** transmits a prompt to a client device of the shopper to select an alternative discrete time interval. This allows the online concierge system **102** to proactively account for numbers of shoppers capable of fulfilling the order during the discrete time interval based on attributes of the order and indicate to the user that the order is unable to be fulfilled during the discrete time interval, enabling the user to adjust the discrete time interval for fulfilling the order before finalizing the order. In some embodiments, the prompt identifies a set of groups that each have a combination of characteristics capable of fulfilling the order from the tags applied to the order to simplify selection of an alternative discrete time interval by the user.

ADDITIONAL CONSIDERATIONS

(58) The foregoing description of the embodiments of the invention has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible in light of the above disclosure.

(59) Some portions of this description describe the embodiments of the invention in terms of algorithms and symbolic representations of operations on information. These algorithmic descriptions and representations are commonly used by those skilled in the data processing arts to convey the substance of their work effectively to others skilled in the art. These operations, while described functionally, computationally, or logically, are understood to be implemented by computer programs or equivalent electrical circuits, microcode, or the like. Furthermore, it has also proven convenient at times, to refer to these arrangements of operations as modules, without loss of generality. The described operations and their associated modules may be embodied in software, firmware, hardware, or any combinations thereof.

(60) Any of the steps, operations, or processes described herein may be performed or implemented with one or more hardware or software modules, alone or in combination with other devices. In one embodiment, a software module is implemented with a computer program product comprising a computer-readable medium containing computer program code, which can be executed by a computer processor for performing any or all of the steps, operations, or processes described.

(61) Embodiments of the invention may also relate to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, and/or it may comprise a general-purpose computing device selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a tangible computer readable storage medium, which include any type of tangible media suitable for storing electronic instructions and coupled to a computer system bus. Furthermore, any computing systems referred to in the specification may include a single processor or may be architectures employing multiple processor designs for increased computing capability.

(62) Embodiments of the invention may also relate to a computer data signal embodied in a carrier wave, where the computer data signal includes any embodiment of a computer program product or other data combination described herein. The computer data signal is a product that is presented in a tangible medium or carrier wave and modulated or otherwise encoded in the carrier wave, which is tangible, and transmitted according to any suitable transmission method.

(63) Finally, the language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the invention be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments of the invention is intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the following claims.

Claims

1. A method, comprising: maintaining, in a data store at an online concierge system, a plurality of discrete time intervals for fulfilling orders received by the online concierge system and information describing a plurality of shoppers, the information describing the plurality of shoppers comprising one or more characteristics of the plurality of shoppers encoded in a tree structure having a plurality of levels, each of the plurality of levels having a value corresponding to characteristics of shoppers in the plurality of shoppers; receiving, by the online concierge system, an order from a client device of a user over a network, the order including one or more items and information specifying a discrete time interval; applying, by one or more processors of the online concierge system, a machine learning model to the discrete time interval to determine an estimated number of shoppers and corresponding levels of the estimated number of shoppers in the tree structure, wherein the machine learning model is trained over historical data describing available shoppers in the tree structure during a plurality of discrete time intervals, training the machine learning model including: accessing a plurality of training examples, each labeled with a discrete time interval and a plurality of shoppers available during the discrete time interval, each shopper corresponding to a level in the tree structure; for each of the plurality of training examples, applying the machine learning model to a corresponding discrete time interval to predict a number of shoppers available during the discrete time interval at each level in the tree structure; determining an error metric by comparing predicted number of available shoppers at each level with corresponding labeled values from the training examples; and updating parameters of the machine learning model to reduce the error metric, thereby improving accuracy of the machine learning model; applying one or more tags to the received order based on the one or more items included in the order, the one or more tags corresponding to levels of shoppers capable of fulfilling the order; grouping the number of estimated shoppers into a plurality of groups based on the levels of the estimated shoppers in the tree structures; for each of the plurality of groups, determining, by the one or more processors of the online concierge system, a score computed based on a combination of levels of the estimated shoppers; identifying one or more groups in the plurality of groups having a combination of levels capable of fulfilling the order; selecting one of the identified one or more groups having a minimum score; selecting an estimated shopper from the selected group to fulfill the order; dispatching, by the online concierge system, the selected shopper for fulfilling the order, wherein dispatching the selected shopper comprises transmitting, over the network, the order to a client device associated with the selected shopper for fulfilling the order, wherein the dispatching causes the client device to display the order to the selected shopper for fulfillment; and decrementing a number of estimated shoppers in the selected group having the minimum score in response to the dispatching.
2. The method of claim 1, wherein the score for a group comprises a product of values corresponding to levels in each of the one or more tree structures including a characteristic of the combination of characteristics.
3. The method of claim 1, wherein a characteristic of a shopper indicates whether the shopper is a member of a warehouse identified by the order.
4. The method of claim 1, wherein a characteristic of a shopper identifies a specific item and indicates whether the shopper is authorized by the online concierge system to purchase or to deliver the specific item.
5. The method of claim 4, wherein the specific item is selected from a group comprising: alcohol and prescription medication.
6. The method of claim 1, wherein receiving the order from the user of the online concierge system including one or more items and specifying the discrete time interval comprises: determining an estimated number of estimated shoppers for the discrete time interval in each of the identified one

or more groups; and responsive to determining each of the identified one or more groups includes less than a threshold number of estimated shoppers, transmitting a prompt to a client device of the user to select an alternative discrete time interval.

7. The method of claim 6, wherein the prompt identifies a set of alternative discrete time intervals each including at least one group having the combination of characteristics capable of fulfilling the order from the tags applied to the order.

8. The method of claim 1, further comprising: modifying a tree structure of a tag included in the determined combination; generated a modified score for a group including the tag having the modified tree structure, the modified score determined from the modified tree structure; receiving an additional order to which the tag having the modified tree structure is applied; and selecting an estimated shopper to fulfill the additional order based on the modified score and scores for other groups having a combination of characteristics capable of fulfilling the additional order from the tags applied to the additional order.

9. A computer program product comprising a non-transitory computer readable storage medium having instructions encoded thereon that, when executed by one or more processors, cause the processor to: maintain, in a data store, a plurality of discrete time intervals for fulfilling orders received from client devices of users and information describing a plurality of shoppers, the information describing the plurality of shoppers comprising one or more characteristics of the plurality of shoppers encoded in a tree structure having a plurality of levels, each of the plurality of levels having a value corresponding to characteristics of shoppers in the plurality of shoppers; receive an order from a client device of a user over a network, the order including one or more items and information specifying a discrete time interval; apply a machine learning model to the discrete time interval to determine an estimated number of shoppers and corresponding levels of the estimated number of shoppers in the tree structure, wherein the machine learning model is trained over historical data describing available shoppers in the tree structure during a plurality of discrete time intervals, training the machine learning model including: accessing a plurality of training examples, each labeled with a discrete time interval and a plurality of shoppers available during the discrete time interval, each shopper corresponding to a level in the tree structure; for each of the plurality of training examples, applying the machine learning model to a corresponding discrete time interval to predict a number of shoppers available during the discrete time interval at each level in the tree structure; determining an error metric by comparing predicted number of available shoppers at each level with corresponding labeled values from the training examples; and updating parameters of the machine learning model to reduce the error metric, thereby improving accuracy of the machine learning model; apply one or more tags to the received order based on the one or more items included in the order, the one or more tags corresponding to levels of shoppers capable of fulfilling the order; group the number of estimated shoppers into a plurality of groups based on the levels of the estimated shoppers in the tree structures; for each of the plurality of groups, determine, by the one or more processors, a score computed based on a combination of levels of the estimated shoppers; identify one or more groups in the plurality of groups having a combination of levels capable of fulfilling the order; select one of the identified one or more groups having a minimum score; select an estimated shopper from the selected group to fulfill the order; dispatch the selected shopper for fulfilling the order, wherein dispatching the selected shopper comprises transmitting, over the network, the order to a client device associated with the selected shopper for fulfilling the order, wherein the dispatching causes the client device to display the order to the selected shopper for fulfillment; and decrement a number of estimated shoppers in the selected group having the minimum score in response to the dispatching.

10. The computer program product of claim 9, wherein the score for a group comprises a product of values corresponding to levels in each of the one or more tree structures including a characteristic of the combination of characteristics.

11. The computer program product of claim 9, wherein a characteristic of a shopper indicates

whether the shopper is a member of a warehouse identified by the order.

12. The computer program product of claim 9, wherein a characteristic of a shopper identifies a specific item and indicates whether the shopper is authorized to purchase or to deliver the specific item based on information describing the plurality of shoppers stored in the data store.

13. The computer program product of claim 12, wherein the specific item is selected from a group comprising: alcohol and prescription medication.

14. The computer program product of claim 9, wherein receiving the order from the user including one or more items and specifying the discrete time interval comprises: determining an estimated number of estimated shoppers for the discrete time interval in each of the identified one or more groups; and responsive to determining each of the identified one or more groups includes less than a threshold number of estimated shoppers, transmitting a prompt to a client device of the user to select an alternative discrete time interval.

15. The computer program product of claim 14, wherein the prompt identifies a set of alternative discrete time intervals each including at least one group having the combination of characteristics capable of fulfilling the order from the tags applied to the order.

16. The computer program product of claim 9, wherein the instructions further cause the one or more processors to: modify a tree structure of a tag included in the determined combination; generate a modified score for a group including the tag having the modified tree structure, the modified score determined from the modified tree structure; receive an additional order to which the tag having the modified tree structure is applied; and select an estimated shopper to fulfill the additional order based on the modified score and scores for other groups having a combination of characteristics capable of fulfilling the additional order from the tags applied to the additional order.

17. A computer system, comprising: one or more processors; and a non-transitory computer readable storage medium having instructions encoded thereon that, when executed by the one or more processors, cause the one or more processors to: maintain, in a data store, a plurality of discrete time intervals for fulfilling orders received from client devices of users and information describing a plurality of shoppers, the information describing the plurality of shoppers comprising one or more characteristics of the plurality of shoppers encoded in a tree structure having a plurality of levels, each of the plurality of levels having a value corresponding to characteristics of shoppers in the plurality of shoppers; receive, an order from a client device of a user over a network, the order including one or more items and information specifying a discrete time interval; apply, by the one or more processors, a machine learning model to the discrete time interval to determine an estimated number of shoppers and corresponding levels of the estimated number of shoppers in the tree structure, wherein the machine learning model is trained over historical data describing available shoppers in the tree structure during a plurality of discrete time intervals, training the machine learning model including: accessing a plurality of training examples, each labeled with a discrete time interval and a plurality of shoppers available during the discrete time interval, each shopper corresponding to a level in the tree structure; for each of the plurality of training examples, applying the machine learning model to a corresponding discrete time interval to predict a number of shoppers available during the discrete time interval at each level in the tree structure; determining an error metric by comparing predicted number of available shoppers at each level with corresponding labeled values from the training examples; and updating parameters of the machine learning model to reduce the error metric, thereby improving accuracy of the machine learning model; apply one or more tags to the received order based on the one or more items included in the order, the one or more tags corresponding to levels of shoppers capable of fulfilling the order; group the number of estimated shoppers into a plurality of groups based on the levels of the estimated shoppers in the tree structures; for each of the plurality of groups, determine, by the one or more processors, a score computed based on a combination of levels of the estimated shoppers; identify one or more groups in the plurality of groups having a combination of levels

capable of fulfilling the order; select one of the identified one or more groups having a minimum score; select an estimated shopper from the selected group to fulfill the order; dispatch the selected shopper for fulfilling the order, wherein dispatching the selected shopper comprises transmitting, over the network, the order to a client device associated with the selected shopper for fulfilling the order, wherein the dispatching causes the client device to display the order to the selected shopper for fulfillment; and decrement a number of estimated shoppers in the selected group having the minimum score in response to the dispatching.

18. The computer system of claim 17, wherein the score for a group comprises a product of values corresponding to levels in each of the one or more tree structures including a characteristic of the combination of characteristics.

19. The computer system of claim 17, wherein a characteristic of a shopper indicates whether the shopper is a member of a warehouse identified by the order.

20. The computer system of claim 17, wherein a characteristic of a shopper identifies a specific item and indicates whether the shopper is authorized to purchase or to deliver the specific item based on information describing the plurality of shoppers stored in the data store.
