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Systems and methods for constructing a narrative of an interaction with a subject

Abstract

Systems and methods for constructing a narrative of an interaction with a subject are disclosed. According to an aspect, a method includes receiving one or more response prompts. The method also includes constructing a data structure including one or more response prompt nodes, wherein the data structure is associated with a topic, wherein each response prompt node is associated with a response prompt, one or more template sentences, and one or more traversal criteria, wherein the response prompt nodes are ordered, wherein the response prompt nodes are linked by edges that are traversable based on a response to a response prompt at the respective node according to one or more traversal criteria. Further, the method includes providing a user interface configured to display one or more response prompts, and display one or more additional response prompts according to one or more traversal criteria of one or more response prompt nodes.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) This continuation-in-part (CIP) patent application claims priority to U.S. Nonprovisional patent application Ser. No. 17/394,360, filed Aug. 4, 2021, and titled SYSTEMS AND METHODS FOR CONSTRUCTING A NARRATIVE OF AN INTERACTION WITH A SUBJECT, which claims priority to U.S. Provisional Patent Application No. 63/061,220, filed Aug. 5, 2020, and titled SYSTEMS AND METHODS FOR CONSTRUCTING A NARRATIVE OF AN INTERACTION WITH A SUBJECT, the content of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD
(1) The presently disclosed subject matter generally relates to note writing and summarization. Particularly, the presently disclosed subject matter generally relates to systems and methods for constructing a narrative of an interaction with a subject.
BACKGROUND
(2) Typically, a physician or other healthcare practitioner is provided with a medical record or access to previously written notes about a patient prior to meeting with the patient. The physician or healthcare practitioner may then review the medical record and/or notes prior to meeting with the patient so that he or she can be better informed about the patient's medical history. In this way, a scheduled appointment with the patient can be more efficiently conducted.
(3) Often, shortly before a scheduled appointment, the patient may complete a questionnaire and/or may be interviewed by a nurse or other healthcare practitioner about the patient's current condition, medical history, and reason for the appointment. This information may be provided to the physician prior to meeting with the patient. There exist electronic-based techniques for acquiring such information. For example, a patient may complete an online questionnaire, the healthcare practitioner may enter the information into a computer while interviewing the patient, or the patient may be provided with a computing device (e.g., a tablet computer) to enter the information. Often this information is entered into a form and the completed form is provided to the healthcare practitioner to review prior to meeting with the patient. Such electronic-based techniques have

improved the relay of information to the healthcare practitioner; however, there is a continuing need to provide improved systems and techniques for interviewing patients and facilitating the provision and documentation of this information in order to reduce the total time required to carry out and document a patient appointment.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) Having thus described the presently disclosed subject matter in general terms, reference will now be made to the accompanying Drawings, which are not necessarily drawn to scale, and wherein:
(2) FIG. **1**A is a block diagram of a system for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure;
(3) FIG. **1**B is a block diagram of a system for construction a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure;
(4) FIG. **1**C is a block diagram of a system for construction of a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure;
(5) FIG. **2** is a flowchart of a method for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure;
(6) FIGS. **3** and **4** are diagrams of example data structures for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure;
(7) FIG. **5** is a tabular representation of an example data structure for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure;
(8) FIGS. **6-67** are images of images of various screenshots of a system in accordance with embodiments of the present disclosure;
(9) FIG. **68** illustrates a screenshot of an example depicting how questions may be displayed by a topic area;
(10) FIG. **69** illustrates a depiction of print or a display of how a QR code may be displayed that a patient can scan in order to access a questionnaire specific to a practice;
(11) FIG. **70** illustrates a screenshot of an example of how a custom list of questionnaire topics may be pinned by practice;
(12) FIG. **71** illustrates a flow diagram of an example method of how a patient-questionnaire matching algorithm may be applied to practice information and/or patient information in order to output one or more questionnaire topics specific to the practice and/or patient information provided;
(13) FIG. **72** illustrates a flow diagram of an example method of how a language model (LM) may be used to construct a knowledge graph data structure; and
(14) FIG. **73** illustrates an implementation of a user interface for a SELECTMANY question, a SELECTMANYDENSE question, and a SELECTONE question. SELECTMANY, SELECTMANYDENSE, and SELECTONE are all multiple-choice questions.
SUMMARY
(15) The presently disclosed subject matter relates to systems and methods for constructing a narrative of an interaction with a subject. According to an aspect, a method includes receiving one or more response prompts. The method also includes constructing a data structure including one or more response prompt nodes, wherein the data structure is associated with a topic, wherein each response prompt node is associated with a response prompt, one or more template sentences, and one or more traversal criteria, wherein the response prompt nodes are ordered, wherein the

response prompt nodes are linked by edges that are traversable based on a response to a response prompt at the respective node according to one or more traversal criteria. Further, the method includes providing a user interface configured to display one or more response prompts, and display one or more additional response prompts according to one or more traversal criteria of one or more response prompt nodes. The method also includes providing a narrative build manager configured to construct text for each response prompt node via insertion of the response into the template sentence, or by using the response to select from a set of template sentences. The manager is also configured to aggregate the text by traversing the nodes according to their connectivity via edges and traversal criteria. Further, the manager is configured to present, via the user interface, a narrative of an interaction with a subject including the aggregated text.

(16) According to another aspect, a method includes constructing a data structure including one or more response prompt nodes, wherein each node is associated with a response prompt and one or more template sentences, wherein the nodes are linked by edges, wherein one or more response prompts is obtained by prompting a language model to produce a response prompt, wherein one or more template sentences is obtained by prompting a language model to produce a template sentence for a response prompt. The method also includes providing a narrative build manager configured to construct text for each response prompt node via insertion of the response into the template sentence, or by using the response to select from a set of template sentences. The manager is also configured to aggregate the text by traversing the nodes according to the connectivity defined by the edges. Further, the manager is configured to present, via the user interface, a narrative of interaction with the subject including the aggregated text.

(17) According to another aspect, a method includes rendering a user interface for a physical examination section, which includes any of the following user interface design elements: a "for all" button at the beginning of a row of buttons which if selected will cause all buttons in that row to select simultaneously; display of related physical examination findings spatially close to one another in the user interface, for example with related physical examination findings all appearing as buttons in the same row; a "left-right" button which if selected will display another adjacent button on the left and another adjacent button on the right for the purpose of indicating which side(s) of the body a finding appears on; a lung sounds widget which is organized with six panels, one panel for each lobe of the lung, and within each panel displaying buttons for lung sounds such as wheezes, rales, or rhonchi; an abdominal exam widget which is organized with 4 panels for the 4 quadrants of the abdomen or 9 panels for the 9 sections of the abdomen, and within each panel displaying buttons for abdominal findings such as tenderness, rebounding, or guarding; a pulses widget which is organized to allow the user to select a pulse location (such as brachial, radial, ulnar, or dorsalis pedis), a pulse side (right or left), and a pulse strength (such as 0, 1+, 2+, 3+, 4+); and a reflexes widget which is organized to allow the user to select a reflex location (such as biceps, brachioradialis, triceps, patellar, ankle jerk, plantar), a reflex side (right or left), and a reflex strength (such as 0, 1+, 2+, 3+, 4+).

DETAILED DESCRIPTION

(18) The following detailed description is made with reference to the figures. Exemplary embodiments are described to illustrate the disclosure, not to limit its scope, which is defined by the claims. Those of ordinary skill in the art will recognize a number of equivalent variations in the description that follows.

(19) Articles "a" and "an" are used herein to refer to one or to more than one (i.e. at least one) of the grammatical object of the article. By way of example, "an element" means at least one element and can include more than one element.

(20) "About" is used to provide flexibility to a numerical endpoint by providing that a given value may be "slightly above" or "slightly below" the endpoint without affecting the desired result.

(21) The use herein of the terms "including," "comprising," or "having," and variations thereof is meant to encompass the elements listed thereafter and equivalents thereof as well as additional

elements. Embodiments recited as "including," "comprising," or "having" certain elements are also contemplated as "consisting essentially of" and "consisting" of those certain elements.

(22) Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. For example, if a range is stated as between 1%-50%, it is intended that values such as between 2%-40%, 10%-30%, or 1%-3%, etc. are expressly enumerated in this specification. These are only examples of what is specifically intended, and all possible combinations of numerical values between and including the lowest value and the highest value enumerated are to be considered to be expressly stated in this disclosure.

(23) Unless otherwise defined, all technical terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs.

(24) The functional units described in this specification have been labeled as computing devices. A computing device may be implemented in programmable hardware devices such as processors, digital signal processors, central processing units, field programmable gate arrays, programmable array logic, programmable logic devices, cloud processing systems, or the like. The computing devices may also be implemented in software for execution by various types of processors. An identified device may include executable code and may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, function, or other construct. Nevertheless, the executable of an identified device need not be physically located together but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the computing device and achieve the stated purpose of the computing device. In another example, a computing device may be a server or other computer located within a retail environment and communicatively connected to other computing devices (e.g., POS equipment or computers) for managing accounting, purchase transactions, and other processes within the retail environment. In another example, a computing device may be a mobile computing device such as, for example, but not limited to, a smart phone, a cell phone, a pager, a personal digital assistant (PDA), a mobile computer with a smart phone client, or the like. In another example, a computing device may be any type of wearable computer, such as a computer with a head-mounted display (HMD), or a smart watch or some other wearable smart device. Some of the computer sensing may be part of the fabric of the clothes the user is wearing. A computing device can also include any type of conventional computer, for example, a laptop computer or a tablet computer. A typical mobile computing device is a wireless data access-enabled device (e.g., an iPHONE® smart phone, a BLACKBERRY® smart phone, a NEXUS ONE™ smart phone, an iPAD® device, smart watch, or the like) that is capable of sending and receiving data in a wireless manner using protocols like the Internet Protocol, or IP, and the wireless application protocol, or WAP. This allows users to access information via wireless devices, such as smart watches, smart phones, mobile phones, pagers, two-way radios, communicators, and the like. Wireless data access is supported by many wireless networks, including, but not limited to, Bluetooth, Near Field Communication, CDPD, CDMA, GSM, PDC, PHS, TDMA, FLEX, ReFLEX, iDEN, TETRA, DECT, DataTAC, Mobitex, EDGE and other 2G, 3G, 4G, 5G, and LTE technologies, and it operates with many handheld device operating systems, such as PalmOS, EPOC, Windows CE, FLEXOS, OS/9, JavaOS, iOS and Android. Typically, these devices use graphical displays and can access the Internet (or other communications network) on so-called mini- or micro-browsers, which are web browsers with small file sizes that can accommodate the reduced memory constraints of wireless networks. In a representative embodiment, the mobile device is a cellular telephone or smart phone or smart watch that operates over GPRS (General Packet Radio Services), which is a data technology for GSM networks or operates over Near Field Communication e.g. Bluetooth. In addition to a conventional voice communication, a given mobile device can communicate with another such device via many different types of message transfer

techniques, including Bluetooth, Near Field Communication, SMS (short message service), enhanced SMS (EMS), multi-media message (MMS), email WAP, paging, or other known or later-developed wireless data formats. Although many of the examples provided herein are implemented on smart phones, the examples may similarly be implemented on any suitable computing device, such as a computer.

(25) An executable code of a computing device may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different applications, and across several memory devices. Similarly, operational data may be identified and illustrated herein within the computing device, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, as electronic signals on a system or network.

(26) The described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, to provide a thorough understanding of embodiments of the disclosed subject matter. One skilled in the relevant art will recognize, however, that the disclosed subject matter can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the disclosed subject matter.

(27) As used herein, the term "memory" is generally a storage device of a computing device. Examples include, but are not limited to, read-only memory (ROM) and random access memory (RAM).

(28) The device or system for performing one or more operations on a memory of a computing device may be a software, hardware, firmware, or combination of these. The device or the system is further intended to include or otherwise cover all software or computer programs capable of performing the various heretofore-disclosed determinations, calculations, or the like for the disclosed purposes. For example, exemplary embodiments are intended to cover all software or computer programs capable of enabling processors to implement the disclosed processes. Exemplary embodiments are also intended to cover any and all currently known, related art or later developed non-transitory recording or storage mediums (such as a CD-ROM, DVD-ROM, hard drive, RAM, ROM, floppy disc, magnetic tape cassette, etc.) that record or store such software or computer programs. Exemplary embodiments are further intended to cover such software, computer programs, systems and/or processes provided through any other currently known, related art, or later developed medium (such as transitory mediums, carrier waves, etc.), usable for implementing the exemplary operations disclosed below.

(29) In accordance with the exemplary embodiments, the disclosed computer programs can be executed in many exemplary ways, such as an application that is resident in the memory of a device or as a hosted application that is being executed on a server and communicating with the device application or browser via a number of standard protocols, such as TCP/IP, HTTP, XML, SOAP, REST, JSON and other sufficient protocols. The disclosed computer programs can be written in exemplary programming languages that execute from memory on the device or from a hosted server, such as BASIC, COBOL, C, C++, Java, Pascal, or scripting languages such as JavaScript, Python, Ruby, PUP, Perl, or other suitable programming languages.

(30) As referred to herein, the terms "computing device" and "entities" should be broadly construed and should be understood to be interchangeable. They may include any type of computing device, for example, a server, a desktop computer, a laptop computer, a smart phone, a cell phone, a pager, a personal digital assistant (PDA, e.g., with GPRS NIC), a mobile computer with a smartphone client, or the like.

(31) As referred to herein, a user interface is generally a system by which users interact with a computing device. A user interface can include an input for allowing users to manipulate a

computing device, and can include an output for allowing the system to present information and/or data, indicate the effects of the user's manipulation, etc. An example of a user interface on a computing device (e.g., a mobile device) includes a graphical user interface (GUI) that allows users to interact with programs in more ways than typing. A GUI typically can offer display objects, and visual indicators, as opposed to text-based interfaces, typed command labels or text navigation to represent information and actions available to a user. For example, an interface can be a display window or display object, which is selectable by a user of a mobile device for interaction. A user interface can include an input for allowing users to manipulate a computing device, and can include an output for allowing the computing device to present information and/or data, indicate the effects of the user's manipulation, etc. An example of a user interface on a computing device includes a graphical user interface (GUI) that allows users to interact with programs or applications in more ways than typing. A GUI typically can offer display objects, and visual indicators, as opposed to text-based interfaces, typed command labels or text navigation to represent information and actions available to a user. For example, a user interface can be a display window or display object, which is selectable by a user of a computing device for interaction. The display object can be displayed on a display screen of a computing device and can be selected by and interacted with by a user using the user interface. In an example, the display of the computing device can be a touch screen, which can display the display icon. The user can depress the area of the display screen where the display icon is displayed for selecting the display icon. In another example, the user can use any other suitable user interface of a computing device, such as a keypad, to select the display icon or display object. For example, the user can use a track ball or arrow keys for moving a cursor to highlight and select the display object.

(32) The display object can be displayed on a display screen of a mobile device and can be selected by and interacted with by a user using the interface. In an example, the display of the mobile device can be a touch screen, which can display the display icon. The user can depress the area of the display screen at which the display icon is displayed for selecting the display icon. In another example, the user can use any other suitable interface of a mobile device, such as a keypad, to select the display icon or display object. For example, the user can use a track ball or times program instructions thereon for causing a processor to carry out aspects of the present disclosure.

(33) As referred to herein, a computer network may be any group of computing systems, devices, or equipment that are linked together. Examples include, but are not limited to, local area networks (LANs) and wide area networks (WANs). A network may be categorized based on its design model, topology, or architecture. In an example, a network may be characterized as having a hierarchical internetworking model, which divides the network into three layers: access layer, distribution layer, and core layer. The access layer focuses on connecting client nodes, such as workstations to the network. The distribution layer manages routing, filtering, and quality-of-server (QoS) policies. The core layer can provide high-speed, highly-redundant forwarding services to move packets between distribution layer devices in different regions of the network. The core layer typically includes multiple routers and switches.

(34) FIG. **1**A illustrates a block diagram of a system **100** for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure. Referring to FIG. **1**A, the system includes a computing device **102** of a notetaker **104** and a computing device **106** of a physician **108**. In this example, the notetaker **104** may be a physician's assistant who is interviewing a patient **110** prior to the patient's **110** appointment with the physician **108**. During the interview, the notetaker **104** may interact with the computing device **102** for receiving response prompts to present to the patient **110** and for receiving responses to the response prompts from the patient **110**. For example, a display **112** of the computing device **102** may display to the notetaker **104** a series of response prompts (e.g., questions or multiple choice prompts) to present to the patient **110**. Examples of the notetaker **104** presenting the response prompts to the patient **110** includes, but are not limited to, showing the

display with the response prompts to the patient **110**, or speaking the response prompts to the patient **110**, or speaking an alternative phrasing of the response prompts with the same meaning to the patient **110**. As the response prompts are presented to the patient **110**, the patient **110** may in turn provide a response to each response prompt. The responses may be received and suitably stored at the computing device **102** or in the cloud. As described in further detail herein, a response may be used to determine one or more subsequent response prompts for presentation to the patient **110**. Further, a narrative of the interaction with the patient **110** may be constructed based on the responses. This narrative can include information about the patient's current condition and medical history. The narrative may be constructed on one or more computing devices. For example, the narrative may be constructed on the patient's device, the physician's device, a device in the cloud, and/or combinations thereof. Subsequently, the narrative may be communicated to the computing device **106** via one or more networks **114** such that the narrative may be presented to the physician **108** via a user interface of the computing device **106**.

(35) FIG. **1**B illustrates a block diagram of a system **100** for construction a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure. Referring to FIG. **1**B, the system includes a computing device **102** used by a patient **110** and a computing device **106** of a physician **108**. Before the patient **110** has an appointment with the physician **108**, the patient **110** may interact with the computing device **102** to receive response prompts and to enter responses to the response prompts. A display **112** of the computing device **102** may display to the patient **110** a series of response prompts (e.g., questions or multiple choice prompts). As the response prompts are presented to the patient **110**, the patient **110** may in turn provide a response to each response prompt. The computing device **102** may be a device belonging to the patient, a device provided by a medical facility, or another device. The responses may be received at the computing device **102**, and suitably stored at the computing device **102** and/or in the cloud. As described in further detail herein, a response may be used to determine one or more subsequent response prompts for presentation to the patient **110**. Additionally, a narrative of the interaction with the patient **110** may be constructed based on the responses. This narrative can include information about the patient's current condition and medical history. Subsequently, the narrative may be communicated to the computing device **106** via one or more networks **114** such that the narrative may be presented to the physician **108** via a user interface of the computing device **106**.

(36) FIG. **1**C illustrates a block diagram of a system **100** for construction of a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure. Referring to FIG. **1**C, the system includes a computing device **102** used by a physician **108**. During the interview, the physician **108** may interact with the computing device **102** to receive response prompts to present to the patient **110**. The physician may receive responses to the response prompts from the patient **110**. For example, a display **112** of the computing device **102** may display to the physician **108** a series of response prompts (e.g., questions or multiple choice prompts) to present to the patient **110**. Examples of the physician **108** presenting the response prompts to the patient **110** include, but are not limited to, showing the display with the response prompts to the patient **110**, or speaking the response prompts to the patient **110**, or speaking an alternative phrasing of the response prompts with the same meaning to the patient **110**. As the response prompts are presented to the patient **110**, the patient **110** may in turn provide a response to each response prompt. The responses may be received and suitably stored at the computing device **102**. As described in further detail herein, a response may be used to determine one or more subsequent response prompts for presentation to the patient **110**. A narrative of the interaction with the patient **110** may be constructed based on the responses. This narrative can include information about the patient's current condition and medical history. The narrative may be constructed on one or more computing devices. For example, the narrative may be constructed on the physician's device, a device in the cloud, and/or combinations thereof. Subsequently, the narrative may be

presented to the physician **108** via a user interface of the computing device **102**.

(37) In accordance with embodiments, the notetaker's computing device **102** or a device in the cloud may include a narrative build manager **116**. The functionality of the narrative build manager **116** described herein may be implemented by hardware, software, firmware, or combinations thereof. For example, the narrative build manager **116** may be implemented by memory **118** and one or more processors **120**. The manager **116** may use a data structure including a set of nodes. Each node can correspond to a corresponding one of multiple response prompts for interacting with a subject (e.g., the patient **110**). The nodes can be linked, and each link can be traversable based on a response to a response prompt at the respective node. The manager **116** is configured to receive one or more responses to one or more response prompts of the set of nodes, to use the one or more responses to traverse the links, and to construct a narrative of an interaction with a subject based on the traversal of the links and the one or more responses to the one or more response prompts at one or more nodes. Further, the narrative may be communicated to the physician's computing device **106** for presentation to the physician **108**.

(38) FIG. **2** illustrates a flowchart of a method for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure. The method is described by example as being implemented by the system **100** shown in FIG. **1**, but it should be understood that the method may be implemented by any suitable system.

(39) Referring to FIG. **2**, the method includes receiving **200** response prompts for interacting with a subject. Response prompts can include, but are not limited to questions and/or multiple choice prompts. One or more of the nodes may be associated with a template sentence in addition to a response prompt. For example, a node may be associated with a response prompt "When did the symptoms start?" and with a template sentence "The symptoms started on." The response prompts can each be a request for health-related information about the subject for use in building a narrative of the subject's health based on an interview of the subject. In examples, response prompts can include prompts for input of the subject's history of present illness, medication usage, allergies, family health history, past medical history, surgical history, social history, physical examination findings, review of systems, and/or discussion and plan.

(40) In accordance with embodiments, response prompts may be input by a user for use in constructing a linked data structure. For example, a user of the computing device **102** may use an application residing thereon to input response prompts. Further, the user may input an indication of an ordering of and an interrelation of the response prompts. Construction of the data structure may include linking the nodes based on the received user input that indicates the ordering of and an interrelation of the response prompts. Further, the user may input a template sentence for each node in addition to a response prompt for each node. A data structure may be, for example, a data tree structure. Nodes may include a parent node and two or more child nodes that are each linked to the parent node, and where the links between the parent node and the child nodes are traversable based on a response to a response prompt at the parent node. The user may input information about the nature of the responses that induce traversal from a parent node to a child node.

(41) The method of FIG. **2** includes constructing **202** a data structure including a set of nodes. Each node corresponds to one of the response prompts. The nodes are linked, and each link is traversable based on a response to a response prompt at the respective node. The computing device **102** or another computing device may construct a data structure including a set of nodes in which each node corresponds to one of the response prompts. The nodes may be linked and traversable based on a response to a response prompt at the respective node.

(42) The method of FIG. **2** includes receiving **204**, at a narrative build manager, one or more responses to one or more response prompts of the set of nodes. The notetaker's computing device **102** can receive, via a user interface **122**, responses to one or more of the response prompts. The responses may be input by the notetaker **104** by use of the user interface **122**. For example, the notetaker **104** may interview the patient **110** by presenting a series of the response prompts to the

patient **110**. The responses may also be input by the patient **110**.

(43) The method of FIG. **2** includes using **206**, at the narrative build manager, the response(s) to traverse the links. The ordering of the presentation of the response prompts can be based on the responses given by the patient **110** and input into the computing device **102**. Particularly, the manager **116** can traverse the links between nodes based on the responses, thus presentation of a series of response prompts can be different depending on the responses.

(44) The method of FIG. **2** includes constructing **208**, at the narrative build manager, a narrative of an interaction with a subject based on the traversal of the links and the response(s) to the response prompt(s) at the nodes. The manager **116** can construct a narrative of an interaction with the patient **110** based on the traversal of the links and the responses to the response prompts at the nodes. The narrative can include text in the form of multiple sentences. The manager **116** can construct the sentences based on a structure linking the nodes and/or based on the responses to the response prompts at the nodes. Further, the narrative can include text in the form of multiple paragraphs. The manager **116** can construct the paragraphs based on a structure linking the nodes and/or based on the responses to the response prompts at the nodes. The manager **116** may be configured to construct a sentence based on a template sentence and a received response to the response prompt for that node.

(45) The method of FIG. **2** includes presenting **210** the narrative via a user interface. The constructed narrative may be constructed at the notetaker's computing device **102** and may be stored in memory **118** and presented via the display **112** of the notetaker's computing device **102**. Or, for example, the manager **116** may communicate the narrative to the physician's computing device **106** via the network(s) **114**. The computing device **106** may suitably store and present the narrative to the physician **108**.

(46) In accordance with embodiments, systems and methods disclosed herein may be implemented via a website accessible by a web browser residing on a computing device that has Internet access. Systems and methods disclosed herein may also be implemented via a desktop application or mobile device application. In an example, the website or application can have functionality for implementing an intelligent medical notes assistant. The assistant can be used to generate a medical note in plain text, rich text, or another file format. The generated medical note can be copy-pasted into any electronic medical record. By use of the medical notes assistant, medical note writing can be accelerated and also well-organized data can be obtained for use in building machine learning applications. Various medical note sections may be included in a generated note, including, but not limited to, the history of present illness (HPI), past medical history (PMH), past surgical history (PSH), medications, allergies, family history (FH), social history (SH), review of systems (ROS), physical examination (PE), and discussion and plan.

(47) In an example, a history of present illness section can be a disease-specific part of the note, for example describing why the patient sought medical care today. The history of present illness section and other note sections can be generated using disease-specific medical knowledge graphs. For example, there is a knowledge graph related to "headache" and another knowledge graph related to "chest pain." In an example, each node in the knowledge graph can be a question. For example, the question "Are you dizzy?" is the root node of the "Dizziness" knowledge graph. A node can lead to more nodes ("children") depending on the patient's response. For example, if a node question is "Are you dizzy?" and the patient's response is "Yes" then that leads to the child nodes (a.k.a. "follow-up questions" or "child questions") "When did the dizziness start?" "Do you feel the room spinning around you?" "Do you feel nauseated?" and other child nodes.

(48) In accordance with embodiments, a system disclosed herein can provide basic knowledge graphs such as graphs for chest pain, headache, shortness of breath, and numerous other complaints, diseases, symptoms, and/or conditions.

(49) Example Workflow with Pre-Interview of Patient: In accordance with embodiments, an example workflow may begin with pre-interview of a patient so that a doctor receives a generated

note before they have seen the patient. This reduces the amount of time that the doctor must spend collecting basic information and thereby allows the face-to-face time between the doctor and patient to be focused on more complex medical interviewing, responding patient questions, and physical examination. Example steps follow: 1) Clinic requests that a patient response a system questionnaire before the appointment. A system questionnaire may replace paper forms, may replace competing patient questionnaire software, or may provide a new service for a clinic that previously did not use any pre-appointment questionnaires. 2) Patient fills out the questionnaire using a desktop computer or mobile device, either at home or in the clinic. 3) Patient submits completed questionnaire, which is routed to the doctor. 4) Doctor opens questionnaire: To view the generated note To edit the text of the generated note directly To use the system's interface to edit the patient's information 5) At the end of the patient visit, the doctor copies the generated note into their electronic medical record. Note that if the patient used a template created by their doctor, then the generated note may be in the exact format that the doctor specified.

(50) Example Workflow During Interview of Patient: In accordance with embodiments, in another example user workflow a clinician can use the questionnaire while they are interviewing a patient, for example by clicking buttons, making selections from menus, or typing in the patient's responses to the questions. This workflow can have the goals of accelerating the process of gathering information during a patient interview, assisting in an interview for a rare disease by reminding the doctor of what questions to ask for that disease, or assisting in medical student education by reminding the medical student of what questions to ask for that disease. Example steps follow: 1) When a patient arrives, the doctor opens a questionnaire for that patient. 2) The doctor fills out the questionnaire by verbally asking the patient the questions and filling in the responses using the system's efficient user interface. 3) The doctor copies the final generated note out of the system's product and into the electronic medical record.

(51) A description of an example website in accordance with embodiments of the present disclosure is provided in the following table

(52) Example Website Description

(53) Throughout, the word "template" or "questionnaire" may refer to a knowledge graph data structure, a data structure of linked nodes, and/or another data structure that specifies the content of a particular note section.

(54) TABLE-US-00001 Page Description Landing page This page may include pinned templates, frequently accessed templates, pinned template combinations, and/or access to previously written notes. This page may include buttons or links that allow a user to create a new blank note, edit an existing note, create a new note template, and/or edit an existing note template. Note browsing This page enables the user to browse notes that they have page previously created. These notes may be completed or in progress. Template This page enables the user to browse different templates, such as browsing page templates for different diseases related to the History of Present Illness section, templates for different Physical Exam sections, and/or templates for different Review of Systems sections. Login page On this page the user inputs their username and password. Single- factor or multifactor authentication may be used. Account page On this page the user can enter or update personal information about themselves such as first name, last name, phone number, address, email address, preferred pronouns, location, payment information. and associated medical facilities or clinicians. About us On this page the user can read about the company's mission and/or team. Contact us On this page the user can send the company feedback, suggestions for how to improve the product, comments, or questions. Recommendation This feature enables the user to recommend the product to a friend. Create HPI History of Present Illness. This section focuses on why the patient Note is in a medical facility today. This section uses disease-related knowledge graphs either provided by Cydoc or created by a user. The user selects which diseases, conditions, and/or symptoms are relevant to the patient's visit today. Then the knowledge graphs for each of those selected diseases, conditions, and/or symptoms are used to display questions to the user in a

dynamic way through a user interface. The questions that are displayed may change depending on the user's responses. This process is inspired by the way in which a doctor's questions may change depending on a patient's responses to previous questions. The History of Present illness includes a carefully designed user interface to allow efficient responding of questions, and display of questions is different depending on the question type. PMH Past Medical History: This section enables a user to enter information about a patient's past medical history, including past diagnoses, yes or no for whether the patient has the diagnosis, onset of the diagnosis, whether the condition has resolved, date of resolution, and/or comments. PSH Past Surgical History: This section enables a user to enter information about a patient's past surgical history, including the procedure name, the procedure date, and/or comments. Meds Medications and Supplements: This section enables a user to enter information about a patient's medications, including the medication name, start date, whether the patient is currently taking the medication, end date, schedule, dose, reason for taking, side effects, and/or comments. Allergies Allergies: This section enables a user to enter information about a patient's allergies, including the inciting agent, type of reaction, and/or comments. FH Family History: This section enables a user to enter information about their family history, including diagnoses, whether the patient's family includes anyone with that diagnosis, which family member(s) had or have the condition, whether the condition was the cause of death for each family member, and/or comments. SH Social History: This section enables a user to enter information about a patient's social history, including tobacco use, alcohol use, recreational drug use, living situation, employment, diet, and exercise. For substance user, the user can enter information about the specific kinds of substances used, the quantity of substances used, the duration of time substances have been used, the method by which substances are used, whether the patient is interested in quitting, and/or whether the patient has tried to quit before. ROS Review of Systems: This section enables a user to enter whether or not a patient is experiencing particular symptoms. The symptoms are organized according to body system or other topical grouping. PE Physical Exam: This section enables a user to enter information about a patient's physical examination findings. The physical exam includes a carefully designed user interface to allow efficient recording of normal and abnormal findings by clicking on buttons, using widgets, and/or using auto-populating drop-down menus. Physical exam findings that have a particular side (for example, right vs. left eye, right vs. left ear) are displayed using buttons that expand to include a "right" indicator and a "left" indicator when clicked, so that the user may specify the side(s) of the physical exam finding. Custom widgets enable efficient entering of lung sounds, abdominal quadrant findings, heart murmurs, tendon reflexes, and pulses. Buttons may be colorized according to whether a physical exam finding is normal or abnormal, for example green for normal and red for abnormal. Plan Discussion and Plan This section is important for future machine learning applications. This is also an important section in a medical note. Here the user specifies what they think the diagnosis is, and they describe the treatment plan. Fields may include: Differential Diagnosis: here the user can enter what they think the differential diagnosis is and why. For example, the differential diagnosis for headache might be, "Migraine, Tension Headache, Dehydration." Plan (Medications): the user can write down detailed information about any medications they intend to prescribe to treat the patient's condition, including information about the medication dose and schedule. Plan (Procedures/Services): the user can write down what procedures (e.g. appendectomy, electrocardiogram) they intend to order to treat the patient's condition. Referrals/Consults: the user can write down if the patient should see any specialists, go to a hospital, etc. Example additional fields (which are not usually part of a Discussion and Plan but which are included for downstream machine learning purposes): How sick is the patient on a scale of 1 (healthy) to 10 (critically ill)? Will the patient be sent to the emergency department? Will the patient be admitted to the hospital? What other questions were asked to the patient that were not part of the existing template? Additional fields beyond the ones listed may be included as well. Generate This page summarizes the entire note in free text, rich text, or Note another format that

enables the user to copy and paste the generated note into an electronic medical record or transfer the generated note into an electronic medical record in some other manner. The Generate Note section has various parts: The History of Present illness section is displayed as free text that is generated based on user responses to response prompts, template sentences, machine learning processing steps, and/or rule-based processing steps. Additional data about the patient may be represented in text using whitespace to make sure it displays as a table, in rich text using a table format, or in free text. The point of the "Generate Note" functionality is to allow the user to copy all of the note information from the user interface into whatever electronic medical record their hospital or clinic is using. Create Template: The Create Template: History of Present Illness feature enables a History of Present user to create a custom template for a particular disease, condition, Illness or symptom. This custom template may be a knowledge graph that can be used in the History of Present Illness section of the note. The feature provides a graphical user interface that allows a user to design and input a custom knowledge graph. The user inputs the question text, question type, template sentence, question order, and question relationships. In addition to creating new templates from scratch, users can also edit templates that were previously created by themselves, by others, or by Cydoc. Create Template: On this page a user can create a custom template for a Physical Physical Exam Exam section. The user can specify the words that should appear on or within buttons, widgets, and/or auto-populating dropdown menus. They can specify whether particular buttons correspond to normal or abnormal physical exam findings, which can change the display color of these buttons. They can specify whether particular buttons correspond to findings that can be found on the left and/or right side of the body, in which case the button may include the functionality of popping out a left indicator or right indicator when it is first tapped so that the user may select on which side(s) of the body the finding is observed. The user can specify the locations on the page that different user interface elements should appear, and/or the relative ordering in which different user interface elements should appear. Create Template: On this page a user can create a custom template for a Review of Review of Systems section. The user can specify which sections to include, Systems and what the title of each section should be. They can specify what words should appear within each section. Tutorial This page provides a written, drawn, photographed, and/or video explanation of how to use the product: how to fill out a note, what the generated note looks like, how to use the Create Template functionality, what the different question types mean, etc.

(55) Multiple Devices and/or Users: It can be assumed that people may use this product across multiple devices and/or users even for the same note. For example, a doctor may fill out one note partially on their phone and partially on two different desktop computers in different parts of the hospital. Automatic saving of data may be enabled to ensure no data is lost when a user transitions between devices. It can be assumed that people may also use this product across a single device; for example, a doctor may fill out one note entirely on a single hospital computer.

(56) Proper Display on Varying Screen Sizes: It can be assumed that people may use this product on any computing device, including desktop computers and mobile devices. The website or application may display differently on mobile devices than desktop computers, with custom interfaces optimized for smaller or larger screens respectively.

(57) Numerous Uses: Systems disclosed herein can be used in human medicine, veterinary medicine, social work, psychology, physical therapy, occupational therapy, chiropractic, optometry, and all professions in which a patient (human or animal) has a physical, mental, or social issue that must be evaluated through structured questioning and summarized in a written note. A user may be a patient, doctor, nurse, physician assistant, nurse practitioner, veterinarian, dentist, social worker, psychologist, physical therapist, student, secretary, and/or any other individual who interacts with a patient. Systems disclosed herein can also be used in clinical trials, medical research, and other research enterprises that require collecting structured information and summarizing it.

(58) Knowledge Graph: Systems disclosed herein can gather information through a knowledge

graph that enables dynamic patient questioning as well as through customized interfaces for specific note sections. In accordance with embodiments, dynamic patient interviewing can be built or constructed using a knowledge graph with a unique structure. The knowledge graph may consist of disease, condition, or symptom-specific trees that can link to one another. For example, the "Chest Pain" tree can link to the "Aortic Aneurysm" or "Pulmonary Embolism" trees. The system may come with many disease, condition, and symptom-specific trees built in. In accordance with embodiments, each disease, condition, or symptom-specific tree may be associated with the following elements: Body System: this indicates the body system related to the disease or condition. E.g. "Cardiovascular," "Respiratory," "Gastrointestinal" etc. Category: this indicates the name of the disease or condition, e.g. "Chest Pain", "Headache", "Diabetes," etc.

(59) Example Question Nodes (Response Prompt Nodes) of Knowledge Graph Data Structure. A knowledge graph can be created from Question Nodes. Each Question Node of the knowledge graph may be defined by some or all of the following attributes:

(60) TABLE-US-00002 Example Attribute Data Type Description ID string An alphanumeric identifier that uniquely identifies the node Root Indicator 0 or 1 If equal to 1, indicates that this node is the root of a tree. If equal to 0, indicates that this node is not the root of a tree. Question/ string The question text itself. For example, "Did the chest Response pain come on suddenly?" "Do you have high blood Prompt pressure?" "Have you had any recent operations on your heart or arteries?" or "Select any of the following symptoms you are experiencing: headache, drowsiness, chest pain, shortness of breath." Question Type/ string There are at least 13 basic question types which are Response described in more detail below in the "Question Prompt Type Types" section. Body System string A string describing what body system is related to this node. For example, the body system may be one of the body systems in this list: Cardiovascular/Hematologic, Dermatologic, Endocrine, Gastrointestinal, General/Lifestyle, Genitourinary, HEENT, Immune, Neurologic/Psychiatric, Pain, and Respiratory. Category string A string describing more specifically what disease, symptom, or condition is related to this node. For example, the category could be ALLERGY, ANXIETY, or AORTIC_ANEURYSM. Creation Time DateTime A timestamp for when the node was created. Note Section string A string describing what note section relates to this node. For example, the note section could be "HPI" (for History of Present Illness) or "ROS" (for Review of Systems). Patient View string A string with a patient-friendly description of the Category. For example, "Feeling Anxious" for Category ANXIETY. Doctor View string A string with a doctor-targeted description of the Category. For example, "Generalized Anxiety Disorder" for Category "ANXIETY." Response string Specifies what kind of response triggers traversal to Leading to the child nodes of this node. For example, if the More Questions Response Leading to More Questions is "Yes" then this means a "Yes" response will cause the algorithm to ask the questions specified as child nodes. Child Nodes list of The alphanumeric identifiers of the nodes considered strings children of this node. Template string or A template sentence (or set of template sentences) that Sentence list of will be used in the generation of the initial version of strings the medical note. For example, "The patient has a family history of RESPONSE" may be the template sentence for the question "Does the patient have a family history of diabetes or kidney disease?" If the patient selects "diabetes" then the resulting sentence will be "The patient has a family history of diabetes." Template string A template sentence that is relevant if this is a yes or Sentence for no question and the answer is yes. For example, "The Yes patient has a headache." Template string A template sentence that is relevant if this is a yes or Sentence for No no question and the answer is no. For example, "The patient does not have a headache." Doctor Created string The unique Doctor ID of the doctor that created this question. If Cydoc created this question then Doctor Created will indicate that Cydoc created the question.

(61) Example Additional Nodes: To enable computationally efficient querying of the knowledge graph data structure, additional specialized kinds of nodes may be included. Examples of additional specialized kinds of nodes are Doctor Nodes and Category Nodes.

(62) Doctor Nodes (or "Author Nodes"): As an example, Doctor Nodes may be included in a knowledge graph in addition to Question Nodes. A Doctor Node connects to one or more Question Nodes. A Doctor Node is associated with a doctor attribute that stores information about the doctor that created one or more Question Nodes. A Doctor Node may connect to any Question Node for which the doctor attribute of the Doctor Node matches the doctor attribute of the Question Node. If a "root node" indicates the root node of all Question Nodes related to a particular Category, then a Doctor Node may connect to all "root nodes" for which the doctor attribute of the root node matches the doctor attribute of the Doctor Node. A Doctor Node may be associated with some or all of the following attributes: User ID (a unique identifier of the doctor), Creation Time (a timestamp for when a doctor was created), Name (the name of the doctor), Graph ID (an identifier for a graph), Roots (identifiers for the roots of all the graphs that a doctor has created), and/or Questions (identifiers for all the questions that a doctor has created). One use of Doctor Nodes is to increase the speed at which all the Question Nodes created by a particular doctor can be retrieved. Doctor Nodes can enable more efficient querying of Question Nodes according to the identity of the doctor who created those Question Nodes. Note that the use of the word "Doctor" does not restrict this description only to physician users; here a "Doctor" refers to any user of the product regardless of their professional background.

(63) Category Nodes: As an example, Category Nodes may be included in a data structure in addition to Question Nodes. Category Nodes may be created from a set of all unique categories retrieved from the Category attribute of Question Nodes in a knowledge graph. Category Nodes may also be created from a set of all unique elements retrieved from any attribute of Question Nodes in a knowledge graph. A Category Node may be restricted to only connect to other Category Nodes. If "disease subgraph" refers to a collection of Question Nodes that all share the same disease Category and their connections to each other, then a purpose of Category Nodes may be to exemplify conceptual connections between different disease subgraphs within the knowledge graph. The Category Nodes may reflect what disease categories are connected to one another, which in turn may enable more efficient implementation of truncated graph traversal by category. For example, if a user requests all of the "Chest Pain" Question Nodes, the Category Nodes may enable efficient identification of which other categories are connected to chest pain (such as pain, shortness of breath, pulmonary embolism, pneumothorax, and/or diet). In turn, the categories connected to each of these categories can be identified (e.g. all categories connected to pneumothorax) and it may become possible to easily decide "how far out to go" when traversing disease categories. A limit may be set on "how far out to go" for a category. A Category Node may be defined by the following attributes: Category Node ID (a unique identifier), Category (a string describing the category), Creation Time (time stamp for when a node was created), and/or Child Categories (a list of categories that this category node is related to, for example a list of all categories that this category is connected to according to Question Node connectivity). Note that Category Nodes may be created based on the disease Category attribute of Question Nodes, but Category Nodes could also be created based on any other attribute or collection of attributes of Question Nodes, for example the Patient View, Doctor View, Body System, and/or Note Section.

(64) Example Question Types. Nodes in the knowledge graph may be associated with the attribute "Question Type." In examples, there can be at least 13 different question types, which are displayed differently to the user to enable efficient data collection. When users are creating their own custom knowledge graphs, the user can specify the question type of each question that they write.

(65) TABLE-US-00003 Example Question Types Question Type Definition Example Display YES-NO a yes or no question "Do you have Question text followed by a chest pain?" button for "Yes" and a button for "No" CLICK- a multiple-choice "Are you Question text followed by BOXES question for which the suffering any of separate buttons for each of user can select all, the following the possible response choices some, or none of a symptoms? predefined set of headache, response choices dizziness, vision changes" SHORT- free-text response "What happened Question

text followed by a TEXT before you fell?" text box LIST- list of text responses "What foods did Question text followed by TEXT you eat while multiple short text boxes for traveling?" the list elements. The user can add additional list elements or can delete existing list elements. In the user interface, each list element may be implemented using a search-select drop down, such that when a user begins typing they see related answer choices appear which they then have the option to select. NUMBER numerical value "How many Question text followed by a centimeters is box that accepts numerical the laceration?" input SLIDING numerical value on a "On a scale of 1 Question text followed by a SCALE sliding scale to 10, how slider that the user can drag would you rate to any number between your pain?" predefined numerical upper and lower limits. TIME numerical value plus "At what age did Question text followed by a time units of minutes, your child first numerical value box and hours, days, weeks, smile?" buttons for the time units. months, or years. BODY- a question asking "Where is the Question text followed by a LOCATI about the body pain?" diagram of the body that the ON location of a particular user can click to select symptom different regions. Or, question text followed by buttons for different body locations, organized according to body location.

(66) In accordance with embodiments, an "Unsure" option may be implemented in instance of "Yes"/"No" options for use when a user is "unsure." Providing an "unsure" option helps avoid circumstances in which a user leaves a question blank or in which a user arbitrarily chooses a "yes" or "no" response when they are truly uncertain.

(67) Example Special Question Types BLANK and POP: It is desirable to reduce repetitive information entry within a single visit. Therefore, to make information gathering as efficient as possible, the product may include special question types in the knowledge graph that enable synchronization between the History of Present Illness section and other topic-specific note sections. These special question types are MEDS-BLANK, MEDS-POP, PMH-BLANK, PMH-POP, PSH-BLANK, PSH-POP, FH-BLANK, and FH-POP. MEDS-BLANK and MEDS-POP enable synchronization between the medications section and the HPI. PMH-BLANK and PMH-POP enable synchronization between the past medical history section and the HPI. PSH-BLANK and PSH-POP enable synchronization between the past surgical history section and the HPI. FH-BLANK and FH-POP enable synchronization between the family history section and the HPI.

(68) When a patient responds to one of these special question types in the "History of Present Illness" section, the information they enter will automatically appear in the appropriate topic-specific section (e.g. "Medications") and vice versa. "BLANK" means that a custom interface related to the corresponding section is shown, with all entries blank and nothing prepopulated. For example, a MEDS-BLANK question means a blank medications interface is shown. If a patient enters data into a MEDS-BLANK question within the HPI, the Medications section will be synchronized with the data the patient entered. "POP" means that a custom interface related to the corresponding section is shown, with the identifying column prepopulated according to a list specified in a database. The identifying column could be a medication name, disease name, or procedure name, for example. The interface may additionally include a "Yes/No" option so the user can specify if a particular entry applies to them. Information entered in to the interface will be synchronized with the corresponding topic-specific note section.

(69) In an example for a "POP" question, a MEDS-POP question may be: "Are you taking any of the following medications? metformin, insulin, azithromycin." The display for that question in the HPI will be a custom medications interface with metformin, insulin, and azithromycin shown. There will be a Yes/No option associated with each of the medications so that the patient can check "yes" if they are taking the medication and "no" if they are not All medications that the patient is taking (i.e., for which the response is yes) will be synchronized with the table in the Medication section. In an alternative implementations, all medications (i.e., for which the response is yes or no) may be synchronized with the table in the Medications section.

(70) TABLE-US-00004 Question Type Definition Example Display PMH- Past medical "What

conditions have This will display with a BLANK history, blank you been diagnosed past medical history with?" interface. MEDS- Medications, "What medications are This will display with a BLANK blank you taking?" medications interface. FH- Family history, "What conditions have This will display with a BLANK blank members of your family family history interface. been diagnosed with?" PSH- Past surgical "What operations or This will display with a BLANK history, blank procedures have you past surgical history undergone?" interface. PMH-POP Past medical "Have you ever been This will display with a history, diagnosed with any of the past medical history prepopulated following conditions? interface, with the diabetes, kidney disease, prespecified conditions heart attack" prepopulated. MEDS- Medications, "Are you taking any of the This will display with a POP prepopulated following medications? medications interface, aspirin, metformin, with the prespecified acetaminophen." medications prepopulated. FH-POP Family history, "Has anyone in your This will display with a prepopulated family ever been family history interface, diagnosed with any of the with the prespecified following conditions? conditions prepopulated. diabetes, kidney disease, heart attack" PSH-POP Past surgical "Have you ever This will display with a history, undergone the following past surgical history prepopulated operations? appendix interface, with the removal, gallbladder prespecified conditions removal" prepopulated.

(71) Example Node Order: Nodes in a knowledge graph may be ordered. Node order may be determined by an attribute of one or more nodes, or node order may be determined by one or more attributes of one or more edges (links between nodes). The attribute(s) that determine node order may be composed of one or more symbols, letters, numbers, and/or another representation. An ordering of Question Nodes can be useful in the generation of text. A sentence may be produced from a Question Node based on the template sentence and the user answer. Multiple sentences may be produced from multiple Question Nodes. The ordering of Question Nodes can determine an ordering of multiple sentences. For example, if one sentence is generated per node, the ordering of nodes may be used to define the ordering of generated sentences.

(72) Node Order per Node Attribute: An ordering of nodes in a knowledge graph may be defined by an attribute assigned to one or more nodes. This Node Order attribute may store a value that indicates an ordering of nodes. For example, if there are three nodes, the first may have a Node Order attribute of "1", the second may have a Node Order attribute of "2", and the third may have a Node Order attribute of "3" which thus defines a numerical ordering of these nodes. For example, if there are two nodes, the first may have a Node Order attribute of "a" and the second may have a Node Order attribute of "b" which thus defines an alphabetical ordering of these nodes.

(73) Node Order per Edge Attribute: An ordering of nodes in a knowledge graph may be defined by one or more attributes assigned to one or more edges. This Edge Order attribute may store a value that indicates an ordering of nodes via indicating an ordering of edges. For example, if there are three nodes referred to by "abc," "def," and "ghi" and "abc" connects to "def" by an edge with Edge Order "1", and "abc" connects to "ghi" by an edge with Edge Order "2", then that defines a numerical ordering of these nodes starting with "abc" and proceeding to "def" and then to "ghi." There may also be multiple edge attributes that define an ordering of edges, for example edge attributes "From Node Order" and "To Node Order." The attribute "From Node Order" can store a value indicating the order of this edge's parent node, while the attribute "To Node Order" can store a value indicating the order of this edge's child node.

(74) One benefit of storing the node order as an attribute or attributes of edges is that this may prevent the need to duplicate nodes any time the node order is changed. In some cases, it may be advantageous to avoid ever deleting nodes because users may want to define custom graphs based on existing nodes, and later deletion of nodes could disrupt these custom user-created graphs. If node order is stored with edges then there is no need to modify nodes when node order changes; only the edges need to be modified to store the new node order. However, if node order is stored as a node attribute, then any time the node order changes, new nodes need to be created with the new node order, even if all other attributes of those nodes remain the same.

(75) Querying the Knowledge Graph: The knowledge graph may be queried in many ways. The graph may be queried to provide a subset of nodes and/or a subset of edges, according to any attribute or combination of attributes of nodes and/or edges. In examples, the knowledge graph may be queried to obtain all nodes that have a Category of ALLERGY and/or all edges attached to these nodes. The knowledge graph may be queried to obtain all nodes and/or edges that are connected to any node with a Category of ALLERGY including nodes that have other Categories. The knowledge graph may be queried to obtain all nodes and/or edges that were created by a particular user.

(76) Dropdown Menus: Within the topic-specific interfaces (e.g. Medical History, Medications, Family History, or Surgical History) there may be dropdown menus (for example implemented as "Multiple Selection" and/or "Search Selection" and/or "Multiple Search Selection" dropdown menus as defined in React or Semantic UI) for various fields, to enable collection of structured data and to accelerate the process of entering information into the system. The following fields may come with predefined lists of terms accessible through a dropdown interface: diagnoses, procedures, medications, side effects, family members, and symptoms. Diagnosis and procedure terms may be associated with, copied from, or derived from SNOMED Clinical Terms (SNOMED-CT), International Statistical Classification of Diseases and Related Health Problems (ICD), Clinical Classifications Software (CCS), and/or Current Procedural Terminology (CPT) codes.

(77) Topic-Specific Section Loading: It is also desirable to reduce repetitive information entry across different visits. Specifically, the product should not require a user to fill out information in the relatively static topic-specific sections in every visit from scratch. The topic-specific sections are described as "relatively static" because they are unlikely to change substantially from one interview to the next—for example, topic-specific sections may include: Medications (e.g., if the patient is taking metformin now, they will likely be taking it later); Past Medical History (e.g., if the patient has been diagnosed with a heart attack, this will remain part of their medical history for all future visits); Past Surgical History (e.g., if a patient has had their appendix removed, then appendectomy will remain part of their surgical history for all future visits); Allergies (e.g., if the patient is allergic to penicillin, this will remain listed in their allergies section for all future visits); Family History (e.g., if the patient's grandfather died of cancer, this will remain part of the family history for all future visits); Social History (e.g., if the patient has ever smoked tobacco, this will remain part of their social history for all future visits)

(78) In accordance with embodiments, the topic-specific section information may be automatically loaded into the current note interface from the patient's most recent past note and/or from a database that stores the patient's most recent topic-specific section information. Automatically loading the topic-specific sections may increase the speed at which the user can correctly fill in all of the elements of the note interface. The interface may allow the user to edit the information or to "confirm" the information, for example by clicking a button. The database may store the date when the information was last confirmed, as well as which user confirmed it.

(79) Generating a Note or Narrative: In accordance with embodiments, systems and methods disclosed herein can transform questionnaire results into a medical note or narrative based on a knowledge graph structure and artificial intelligence. Systems disclosed herein can transform question-response pairs obtained through the knowledge graph structure into complete, grammatical sentences to produce a coherent medical note. Further, systems disclosed herein can use a rule-based system for the initial sentence generation. The rule-based system may rely on specification of particular question types (e.g. YES-NO, CLICK-BOXES, SHORT-TEXT, NUMBER, TIME, etc.), and specification of a template sentence for each question. The sentences can be formed into paragraphs using the information stored in the knowledge graph structure. For example, the sentences can be concatenated, one after the other, based on the node order defined in the knowledge graph structure and/or the connectivity of nodes in the knowledge graph structure, to produce an overall narrative. As previously described, the node order may be defined using an

attribute of nodes or using one or more attributes of edges.

(80) TABLE-US-00005 Examples of initial text generation through a rule-based system: Template User Input of Sentence(s) for Patient's Question Type Question Text Completion Response Generated Sentence YES-NO Do you have a Yes: The patient Yes The patient reports a headache? reports a headache. headache. No: The patient does not have a headache. YES-NO Do you have a Yes: The patient No The patient does not headache? reports a headache. have a headache. No: The patient does not have a headache. CLICK- How would you The patient's chest burning, The patient's chest pain BOXES describe the pain is _. crushing is burning and crushing. chest pain? burning, crushing, sharp, dull TIME How long ago The shortness of 9 days The shortness of breath did the shortness breath started _ started 9 days ago. of breath start? ago. SHORT-TEXT Please describe In the previous I got up In the previous incident the previous incident where the quickly from where the patient lost incident where patient lost the dinner consciousness, I got up you lost consciousness, table and then quickly from the dinner consciousness. _. fainted onto table and then fainted my couch onto my couch. BODY- Where is the The pain is located right arm The pain is located in LOCATION pain located? in the patient's _. the patient's right arm.

(81) Template Sentences: One or more nodes within the knowledge graph may be associated with a template sentence, which may be used in the note generation process. The table below provides additional examples of template sentences for different Question Types and Question Text, along with User Input of the Patient's Response and the resulting Generated Sentence. The Generated Sentence becomes part of the narrative that is produced. The Generated Sentence is produced by combining the template sentence with the User Input of Patient's Response. For YES-NO questions, the patient's "Yes" or "No" answer determines which of 2 template sentences will be selected to produce the final sentence. For all other question types shown here, the patient's answer is inserted into the template sentence to produce the final Generated Sentence. For CLICK-BOXES questions, both the options that the patient did select (ANSWER) as well as the options the patient did not select (NOTANSWER) may be used in creating the final Generated Sentence. For CLICK-BOXES, LIST-TEXT, or other question types that produce lists of items, commas and the word "and" or the word "of" may be used to join together multiple options.

(82) TABLE-US-00006 Additional examples of sentence generation through a rule-based system, with many examples of Template Sentence(s) for Completion: Template User Input of Question Sentence(s) for Patient's Type Question Text Completion Response Generated Sentence BODY- Where do you feel the The patient feels right calf and The patient feels LOCATION muscle cramps? muscle cramps in right foot muscle cramps in the the ANSWER. right calf and right foot. BODY- Where do you feel the The patient feels left hand The patient feels LOCATION tingling? tingling in the tingling in the left ANSWER. hand. CLICK- Which of the following The patient runny nose, The patient BOXES symptoms do you experiences congestion, experiences runny experience with allergies? ANSWER when watery eyes nose, congestion, and runny nose, congestion, they have allergies. watery eyes when watery eyes, red eyes, The patient denies they have allergies. sneezing, cough, fatigue NOTANSWER. The patient denies red eyes, sneezing, cough, or fatigue. CLICK- Which of the following do The patient fatigue, The patient BOXES you experience along with experiences problems falling experiences fatigue anxiety? feeling restless, ANSWER with asleep and problems falling anxiety. The patient asleep with fatigue, difficulty anxiety. concentrating, irritability, denies The patient denies tense muscles, problems NOTANSWER. feeling restless, falling asleep difficulty concentrating, irritability, or tense muscles. CLICK- When are your joints the The patient's joints in the morning The patient's joints BOXES most painful? in the are the most painful are most painful in morning, in the afternoon, ANSWER. the morning. at night CLICK- Which of the following The patient [blank-no The patient denies BOXES symptoms do you experiences the options were shortness of breath, experience during the day following symptoms selected] chest tightness, (if none, leave blank)? during the day: cough, or wheezing. shortness of breath, chest ANSWER. The tightness, cough,

wheezing patient denies NOTANSWER. CLICK- Do you use insulin from: a The patient uses a pen The patient uses BOXES pen, a bottle and syringe insulin from insulin from a pen. ANSWER. CLICK- Which eye(s) are affected? The following eyes left eye The following eyes BOXES left eye, right eye, both are affected: are affected: left eye. eyes ANSWER. CLICK- Have you had exposure to The patient reports excessive The patient reports BOXES any of the following? exposure to sunlight exposure to radiation , infrared ANSWER. excessive sunlight. radiation, lightning strike, excessive sunlight, high- voltage current FH- Please list the members of The following mother with The following BLANK your family with members of the schizophrenia members of the psychiatric conditions, patient's family have (January 2017), patient's family have their diagnoses, and date a psychiatric brother with a psychiatric when they were diagnosed, diagnosis: anxiety (April diagnosis: mother if applicable. ANSWER 2005) with schizophrenia (January 2017), brother with anxiety (April 2005). FH-POP Do you have a family The patient has a allergies, The patient has a history of: allergies, family history of eczema family history of asthma, ezcema, hay fever ANSWER. The allergies and eczema. patient denies a The patient denies a family history of family history of NOTANSWER asthma or hay fever. FH-POP Does anyone in your The patient reports a Aortic The patient reports a family have a history of family history of dissection in family history of aortic dissection, blood ANSWER. The mother aortic dissection in vessel problems? patient reports no mother. The patient family history of reports no family NOTANSWER. history of blood vessel problems. FH-POP Do you have a family The patient has a rheumatoid The patient has a history of any of the family history of arthritis family history of following? (if none, leave ANSWER. rheumatoid arthritis. blank) rheumatoid arthritis, osteoarthritis LIST- Please list any other ANSWER also peanuts, walnuts Peanuts and walnuts TEXT allergens that trigger your trigger the patient's also trigger the allergies, which you have allergies. patient's allergies. not already listed. LIST- What do you do to try to To reduce their exercising, To reduce their blood TEXT reduce your blood blood pressure, the eating less salt pressure, the patient pressure? patient tries tries exercising and ANSWER. eating less salt. LIST- What foods and drinks do The patient cereal, milk, The patient normally TEXT you normally have for normally eats eggs eats cereal, milk, and breakfast? ANSWER for eggs for breakfast. breakfast. MEDS- Please list the medications The patient is Zyrtec with no The patient is BLANK you are currently taking for currently taking side effects currently taking your allergies in the table ANSWER for their Zyrtec with no side below, including any side allergies. effects for their effects. allergies. MEDS- Please list which The patient has tried Advil The patient has tried BLANK medications you have tried ANSWER to relieve Advil to relieve their for your symptoms. their symptoms. symptoms. MEDS- Please list which The patient has tried Pepcid The patient has tried BLANK medications you have tried ANSWER to relieve Pepcid to relieve for your heartburn. their heartburn. their heartburn. MEDS- Please list which The patient is taking atorvastatin, The patient is taking BLANK medication(s) you are the following colestipol the following currently taking for medications for medications for hyperlipidemia. hyperlipidemia: hyperlipidemia: ANSWER. atorvastatin and colestipol. MEDS- Are you currently taking The patient is glucocorticoids The patient is POP any of the following currently taking currently taking medications? ANSWER. glucocorticoids. glucocorticoids, cholinesterase inhibitors, anticholinergics, sympathomimetics, amphetamines, cocaine NUMBER How many drinks of wine The patient has 2 The patient has 2 do you have in a 24-hour ANSWER drinks of drinks of wine in a period? wine in a 24-hour 24-hour period. period. NUMBER How many episodes of The patient has had 20 The patient has had wheezing have you had in ANSWER episodes 20 episodes of the last 12 months? of wheezing in the wheezing in the last last 12 months. 12 months. PMH- What was your child The patient was pneumonia The patient was BLANK hospitalized for? previously previously hospitalized for hospitalized for ANSWER. pneumonia. PMH- Please fill out the The patient suffered pre- eclampsia, The patient suffered BLANK pregnancy complications in pregnancy gestational pregnancy the table below. complications: diabetes complications: pre- ANSWER. eclampsia and

gestational diabetes. PMH-POP Do you have any of the The patient has the [blank-no The patient does not following conditions? following atopic options were have the following asthma, eczema, hay fever conditions: selected] atopic conditions: ANSWER. The asthma, eczema, hay patient does not fever. have the following atopic conditions: NOTANSWER PMH-POP Do you have a history of: The patient has a Marfan The patient has a aortic aneurysm, Marfan history of syndrome history of Marfan syndrome, Ehlers-Danlos ANSWER. The syndrome. The syndrome, connective patient has no patient has no history tissue disorder, high blood history of of Ehlers-Danlos pressure, atherosclerosis, NOTANSWER. syndrome, smoking connective tissue disorder, high blood pressure, atherosclerosis, or smoking. PMH-POP Do you have a history of The patient has a recent infection, The patient has a any of the following? history of osteoporosis history of recent recent infection, recent ANSWER. The infection and diagnosis of cancer, IV patient denies a osteoporosis. The drug use, osteoporosis history of patient denies a NOTANSWER. history of recent diagnosis of cancer or IV drug use. PMH-POP Have you had any of the The patient has a deep vein The patient has a following in the past? history of thrombosis history of deep vein pulmonary embolism, deep ANSWER. thrombosis. vein thrombosis PSH- Please list the operations The patient has had CABG The patient has had BLANK you have had on your heart recent operations on recent operations on or arteries in the table their heart or their heart or arteries: below. arteries: ANSWER. CABG. PSH-POP Have you had any of the The patient has had stent placement The patient has had following surgeries? open the following the following heart surgery, stent surgeries: surgeries: stent placement, cardiac bypass ANSWER. placement. surgery SCALE1TO10 How would you rate your The patient reports a 7 The patient reports a stress level on a scale of 1 stress level of stress level of 7 out (no stress) to 10 (highest ANSWER out of 10. of 10. stress)? SCALE1TO10 On a scale of 1 (poor) to 10 The patient believes 4 The patient believes (excellent), how well do that they are that they are you think you are controlling their controlling their controlling your blood blood glucose levels blood glucose levels sugar? at a ANSWER out at a 4 out of 10, of 10, where 1 is where 1 is poor and poor and 10 is 10 is excellent. excellent. SCALE1TO10 On a scale of 1 (least fit) to The patient rates 9 The patient rates 10 (most fit), how would their personal fitness their personal fitness you rate your personal as ANSWER out of as 9 out of 10, where fitness? 10, where 10 is 10 is "most fit." "most fit." SHORT- When were you The patient was July 2009 The patient was TEXT hospitalized for an asthma hospitalized for an hospitalized for an attack? asthma attack in asthma attack in July ANSWER. 2009. SHORT- Please describe what The patient I was lifting a The patient describes TEXT caused your back injury. describes their back heavy box and their back injury as injury as follows: felt a sudden follows: I was lifting pain in my a heavy box and felt lower back. a sudden pain in my lower back. SHORT- What did you do The patient states went grocery The patient states TEXT yesterday? that yesterday, they shopping and that yesterday, they ANSWER. walked the dog went grocery shopping and walked the dog. SHORT- What company, The patient works at Costco The patient works at TEXT organization, or institution ANSWER. Costco. do you work for? SHORT- What questions or The patient reports How do I lower The patient reports TEXT concerns do you have? the following my blood sugar? the following questions and questions and concerns: ANSWER concerns: How do I lower my blood sugar? SHORT- What are your exercise The patient has the to run a mile in The patient has the TEXT goals? following exercise 8 minutes following exercise goals: ANSWER. goals: to run a mile in 8 minutes. TIME How long ago was your The patient's last 3 weeks The patient's last last menstrual period? menstrual period menstrual period was was ANSWER ago. 3 weeks ago. TIME How long ago were you The patient was 5 years The patient was diagnosed with asthma? diagnosed with diagnosed with asthma ANSWER asthma 5 years ago. ago. TIME How often do you use your The patient uses 2 hours The patient uses their inhaler? their inhaler every inhaler every 2 ANSWER. hours. Every: their inhaler every TIME When were you diagnosed The patient was 10 years The patient was with COPD? diagnosed with diagnosed with COPD ANSWER COPD 10 years ago. ago. YES-NO Are you currently eating a Yes: The patient is Yes The patient is low-fiber diet? currently eating a

currently eating a low-fiber diet. low-fiber diet. No: The patient does not eat a low-fiber diet. YES-NO Did the pain come on Yes: The patient's No The patient's pain suddenly? pain came on did not start suddenly. suddenly. No: The patient's pain did not start suddenly. YES-NO Did the chest pain come on Yes: The chest pain Yes The chest pain came suddenly? came on suddenly. on suddenly. No: The chest pain did not come on suddenly.

(83) Refining a Note or Narrative: Once the initial note is generated using the rule-based method just described, the text may be altered, updated, edited, rephrased, rearranged, improved, and/or highlighted using machine learning, rules, and other artificial intelligence techniques. The following are some examples of how sentences can be altered, updated, or improved: Machine learning can be used to change verb tense from first person or second person to third person: "In the previous incident where the patient lost consciousness, I got up quickly from the dinner table and then fainted onto my couch".fwdarw."In the previous incident where the patient lost consciousness, they got up quickly from the dinner table and then fainted onto their couch" Rules can be used to create gender-specific language: with target pronouns "female" .fwdarw."In the previous incident where the patient lost consciousness, she got up quickly from the dinner table and then fainted onto her couch." Rules can be used to replace "the patient" alternately with "he/she" or the patient's name: with target gender "female" and name "ANGELA SMITH".fwdarw."In the previous incident where Ms. Smith lost consciousness, she got up quickly from the dinner table and then fainted onto her couch." Rules can be used to perform a "translation" between colloquial terms and medical terms. For example, "shortness of breath"="dyspnea", "heart attack"="myocardial infarction", "fast breathing"="tachypnea" and so on. This "translation" may also be used in data analysis, databases, or other parts of the product.

(84) Create Custom Knowledge Graphs: In accordance with other embodiments, systems and methods disclosed herein can allow users to create custom knowledge graphs. Allowing users to create custom knowledge graphs enables inclusion of an unlimited number of diseases and conditions and symptoms, as users can define a knowledge graph for anything. Furthermore, custom knowledge graphs make the product accessible for any medical specialty, including medical subspecialties that may focus on rare conditions, because users can define custom knowledge graphs for even rare conditions. User knowledge graphs may be aggregated into the system's main knowledge graph. Incorporation of user knowledge graphs into the system's main knowledge graph may lead to improved quality of the system's main knowledge graph because some users of the product may be experts on particular conditions and can thus create the best knowledge graphs possible for those conditions.

(85) The custom knowledge graphs may include custom questions. Each custom question may be paired with a custom template sentence. Example pairs follow: YES-NO question example: "Do you have chest pain?" is paired with the template sentences of "The patient reports chest pain" (for a yes response) and "The patient reports no chest pain" (for a no response.) LIST-TEXT question example: "Please list the foods you ate while traveling" is paired with the template sentence, "The patient ate RESPONSE while traveling." (Thus if the patient listed "meat, cheese, and pears" the produced sentence would be "The patient ate meat, cheese, and pears while traveling.) TIME question example: "How long has this headache lasted?" is paired with the template sentence, "The headache has lasted RESPONSE." (Thus, if the patient typed in "5 hours" the produced sentence would be "The headache has lasted 5 hours.")

(86) Social Networking: In accordance with other embodiments, the system may include a social networking component in which a user can browse, save, and rate custom knowledge graphs created by other users. For example, if 500 different doctors have created different knowledge graphs for "chest pain" then other doctors can "rate" each of these knowledge graphs on a 0-5 star scale, which then enables quantitative determination of the chest pain knowledge graph with the highest average score. Doctors can also "save" knowledge graphs created by other doctors that they want to use in the future. The highest-rated knowledge graphs (closest to 5/5 stars) for "chest pain"

may appear at the top of search results for "chest pain." Thus, the product may have a social component.

(87) Account Types: In accordance with embodiments different account types may be generated. Examples follow:

(88) TABLE-US-00007 User Profiles/Account Types: Account Type Features Patient A patient account may be generated. Account A patient account may enable a patient: To enter demographic information and personal information such as first name, last name, phone number, address, email address, preferred pronouns, and location To fill out questionnaires To match themselves with doctors or clinics. Doctor A doctor account may be generated. Account A doctor account may be intended for a doctor, researcher, physician assistant, nurse, medical student, or other clinician. A doctor account may enable a clinician: To enter information about degrees obtained, degrees in progress, current job, and current institution. To send a patient a questionnaire for the patient to fill out To receive a filled-out questionnaire from a patient To fill out a questionnaire during or after interviewing a patient in order to generate a note quickly To save their most commonly used note questionnaires To match themselves with patients or clinics. To pay for continued access to the product, for example via a monthly subscription fee. Clinic A clinic account may be generated. Account A clinic account may be intended for a clinic, hospital, research group running a clinical trial, or other medical organization. A clinic account may be associated with doctors, researchers, and clinicians. A clinic account can match itself with patients and doctors, and can match patients with doctors or researchers. Manager A manager account may be generated. Account A manager account may be intended for an administrative employee of an organization. A manager account may create new doctor accounts or delete existing doctor accounts. A manager account may pay the product-related fees of associated doctor accounts. Researcher A researcher account may be generated. Account A research account may be intended for a machine learning researcher. The machine learning researcher can submit machine learning models to be trained and evaluated on the system's data.

(89) In accordance with embodiments, a cloud service provider such as Microsoft Azure or Amazon AWS may be used to host the website or application, store the data, and/or run the machine learning models.

(90) In an example where protected health information is stored in a database, numerous different techniques may be incorporated to enable the system to achieve compliance with HIPAA and HITECH regulations, which specify that protected health information must be encrypted while in transfer and at rest, data must be backed up, and user actions must be logged to record who has accessed what data and when.

(91) In another example, a note may be generated based on information that a user entered in to the product's user interface, but no data may be stored in any database, meaning that the user must save the generated note somewhere else outside of the product if they wish to access it in the future.

(92) For data storage and data analysis, automatic or manual tagging of disease and procedure phrases with SNOMED Clinical Terms (SNOMED-CT), International Statistical Classification of Diseases and Related Health Problems (ICD), Clinical Classifications Software (CCS), and/or Current Procedural Terminology (CPT) codes may be used. Automatic tagging methods may include rule-based methods and machine-learning-based methods. Tagging phrases with codes enables better data organization. For example, such tagging can indicate how "anterior STEMI" is related to "myocardial infarction" and how "tuberculous pneumonia" is related to "tuberculosis."

(93) Artificial Intelligence: In accordance with other embodiments, systems disclosed herein can include artificial intelligence built on data collected through the knowledge graph, data collected through the custom interfaces, and/or data available through other public or private sources. Artificial intelligence may include rule-based expert systems, regression, random forests, support vector machines, neural networks, and/or other algorithms.

(94) Some of the artificial intelligence systems may produce results that are used in the Plan section

of the note, for example to show the user possible diagnoses relevant to the differential diagnosis, and/or to show the user possible medications, procedures, services, referrals, and/or consults that may be an appropriate part of the plan for this note. For example, some of the artificial intelligence systems may produce results for the following tasks related to the Plan section: Predict the most likely diagnoses. Predict the medications that should be used for treatment, if any. Predict the procedures or services that should be ordered for treatment or further diagnostic workup, if any (e.g. appendectomy for appendicitis, EKG for abnormal heart rhythm). Predict whether the patient needs a referral or a consult, and if so, what kind of specialist they need to see.

(95) Some of the artificial intelligence systems may produce results that are used to display predictions about the patient, for example results for the following tasks: Predict how sick the patient is on a scale of 1 to 10 where 1=healthy and 10=critically ill/ICU-level illness. This could be helpful in emergency room triage. For example, if a patient is critically ill but was somehow "missed" by the person coordinating triage, the software could identify them as being high risk so they could be seen by a doctor sooner. Predict whether the patient needs to be admitted to the hospital.

(96) Some of the artificial intelligence systems may produce results that are related to the History of Present Illness section and the underlying knowledge graphs, for example results for the following tasks: Predict what other questions to ask the patient. For example, in the Discussion and Plan section of the note interface the doctor may record what other questions they asked the patient that were useful for determining the diagnosis. By combining this data with the questions that the patient was already asked, it may be possible to build a predictive model to predict which additional questions to ask the patient next in the History of Present Illness section. This is an application of artificial intelligence to grow the knowledge graph of questions. Predict how to expand the Cydoc base knowledge graph using custom knowledge graphs defined by the users.

(97) Medical Record Number: Each patient may be assigned a unique identifier, which is effectively a medical record number (MRN). The MRN may be assigned in such a way that from the MRN alone, a given patient is assigned to a training set (70%), validation set (15%), or test set (15%). As an example, if MRNs range from 0-100, then a new patient may be assigned the next sequentially available number between 0 and 70 with a 70% probability, the next available number between 70 and 85 with a 15% probability, or the next available number between 85 and 100 with a 15% probability. The training, validation, and test sets of patients determined in this way may be used in development or evaluation of artificial intelligence systems.

(98) Automatic Formatting of Data: In accordance with embodiments, systems disclosed herein can include a framework to automatically format, preprocess, and/or clean data collected through the knowledge graph and custom interfaces to create tabular data structures. One motivation is to eliminate the need to perform manual data processing every time a new machine learning model must be trained. The tabular data structure (e.g. a pandas dataframe) may include one patient per row and one feature per column. Each feature may be presented in a clean state wherein all elements use the same measurement units and/or are drawn from a well-defined list of options. These tabular structures may be used to train and evaluate machine learning models. The formatting, pre-processing, and/or cleaning of the tabular structures may be determined in software in a flexible and extensible manner so that a developer can select which features to include in a model and how the features should be prepared. Feature preparation may include, for example, conversion into one-hot or multi-hot vectors for categorical variables, normalization using the training set mean and standard deviation, and so forth.

(99) In accordance with embodiments, artificial intelligence, data mining, and medical knowledge may be used to build a diagnosis and treatment knowledge graph that interfaces with the questionnaire knowledge graph in order to make predictions about diagnoses and treatments.

(100) Submission of Models: In accordance with embodiments, systems disclosed herein can include a user interface that allows machine learning researchers to submit machine learning

models to be trained and evaluated on the system's data set. The researchers may not gain access to the data. Rather, they may follow predefined specifications about how to design their model so that it can be applied directly to system's data. The system may include a model library where machine learning researchers can donate models to solve different medical machine learning tasks. Other users (e.g. doctors and patients) can browse these models and apply them to a particular patient.

(101) In an example, workflow for a machine learning researcher may include the following: 1) Write code for a machine learning model that accepts as input a particular kind of data described in the system's specifications. 2) Write code to calculate performance metrics based on the model's predictions. 3) Submit the machine learning model code and performance metrics code to the system. 4) Receive results from the system that report the performance metrics of the specified model on the system's data.

(102) In an example, a workflow for doctors or patient may include the following: 1) Browse available machine learning models. 2) Click on a machine learning model to load it. 3) Submit a patient's data to the machine learning model. 4) Receive predictions from that machine learning model for that particular patient.

(103) Transformation of Printable Questionnaires to Structured Electronic Data: In accordance with embodiments, the system may include printable questionnaires that can be automatically transformed into structured electronic data using artificial intelligence and other techniques. An example use case is to enable clinics to offer their patients paper forms in the waiting room, and then transform these paper forms into electronic data by photographing or scanning the forms. An example workflow follows: 1) A user prints off a questionnaire in a custom format. The printed off questionnaire includes a QR code that indicates which questionnaire the user is filling out (e.g. chest pain questionnaire), and which user is filling it out. Different questions are displayed according to their question type, e.g. with empty bubbles beside the associated text for CLICK-BOXES questions, and with text boxes for SHORT-TEXT questions. 2) The user fills out the questionnaire. For example, a user colors in bubbles of CLICK-BOXES questions and writes out handwritten free text for free text questions. 3) The user photographs the questionnaire and uploads it to the system. The QR code identifies the patient and which questionnaire was filled out. A machine learning system for handwriting recognition converts the free text into electronic text data. A computer vision model converts the other question types into structured data appropriate for that question type. For example, a computer vision model may convert a CLICK-BOXES question type into a table in which one column contains the response choice option and the other column includes a 1 or 0 depending on whether the bubble was filled in or not. 4) The data from the printed-off questionnaire is loaded into the system's custom user interface. A note is generated. 5) The generated note is copied into the electronic health record. 6) The original photographs are stored so that users can reference the pictures to clarify any data that appears confusing.

(104) Smart Patient Intake Form: One or more questionnaires may be presented to a patient or other user and referred to as a Smart Patient Intake Form, Smart Form, Form, or Cydoc Form. Questionnaires, questions, or response prompts may be presented via an application referred to as a Cydoc application.

(105) Question Display: Questions may be displayed by a topic area. For example, all questions related to "Chest Pain" may be displayed together on the same page, and child questions may be automatically displayed after a parent question if a certain answer is given to the parent question. There may be separate tabs for separate topics, e.g. if a patient has selected "Chest Pain," "Diabetes," and "Headache," then there may be separate tabs entitled, "Chest Pain," "Diabetes," and "Headache" respectively, and each tab may contain the questions related to the corresponding topic.

(106) In another example, a user interface may be implemented where only one question is shown to a patient at a time and the patient may or may not be explicitly shown the overall topic or category pertaining to a particular question. For example, all questions related to "Chest Pain" may

be displayed one at a time, one after the other in a sequential manner, so that the grouping by topic is part of the user experience only in that topically related questions appear one after the other.

(107) QR code workflow: A workflow may be implemented in which a QR code is automatically generated for a particular practice based on a unique identifier for that practice. Anyone with access to the QR code will be able to submit questionnaires to that practice. A patient may then scan this QR code with their smartphone, tablet, or other computing device, in order to access, complete, and submit a questionnaire. The patient may scan the QR code upon arriving in the waiting room of a practice, or they may scan the QR code after being moved into a room within the practice.

(108) Link workflow: A workflow may be used in which a link is automatically generated for a particular practice based on a unique identifier for that practice. Anyone with access to the link will be able to submit questionnaires to that practice. A patient may click on this link from any computing device in order to access, complete, and submit a questionnaire. The patient may be sent the link as part of an automated appointment reminder message, within an email, or within a text message. The link may be displayed on the practice's website and the patient may access the link from there.

(109) Custom questionnaire creation by practices: Custom questionnaires may be created for a particular medical practice, institution, business, organization, group, or health system. The custom questionnaires may focus on specialty-specific topics or they may focus on the types of questions that the entity traditionally has asked of subjects via a paper form, medical assistant, staff member, or other workflow. For example, one or more custom questionnaires related to foot health topics may be created for a podiatry practice, or one or more custom questionnaires related to dental health topics may be created for a dental practice. Questionnaires or individual questions or nodes created for a specific practice may be marked as being associated with that practice, for example via a node attribute, or via another node in the graph that specifies the practice and is linked to all nodes created by that practice. Security controls may be implemented such that if questionnaires were created for Practice A, then they are only visible to and usable by Practice A, and will not be visible to or usable by Practices B, C, or D, or any other practice.

(110) Pinning questionnaires by practice: A user interface may be implemented wherein one or more questionnaire topics is "pinned" so that the user interacting with the Cydoc application will see these questionnaire topics displayed. For example, an urgent care may have buttons for different questionnaire topics like "Cold," "Headache," and "Minor Injury" and these button topics represent the questionnaires that have been "pinned." The specific list of questionnaires or topics may be customizable in a user interface. A practice may be able to log in and specify which particular questionnaires should be pinned for that practice. Then, patients engaging with the Cydoc application for that practice may interact with a user interface in which those questionnaire topics are shown in buttons, bubbles, with check boxes, with radio buttons, or via another interface that enables the patient to select one or more questionnaire topics that is relevant to their individual concerns or chief complaints.

(111) Sentence fragments: A text note may be generated from a questionnaire. This text note may be comprised of sentence fragments that do not form complete grammatically sentences. The note may also be comprised of a mixture of sentence fragments and complete sentences.

(112) Additional question types: Additional question types may be implemented as described in the below table:

(113) TABLE-US-00008 Question Type Description SELECTMANY A multiple-choice question where the user may select zero, several, or all answer choice options. Each answer choice option is displayed on its own line with a Yes button and a No button available. Permits each answer choice option to be unanswered, explicitly Yes, or explicitly No. SELECTMANYDENSE Same as SELECTMANY except that each answer choice option is displayed in a bubble that may be clicked or unclicked. Permits each answer choice option to be unanswered or explicitly Yes. This offers a more condensed user interface but does not enable the explicit No information to be collected.

SELECTONE A multiple-choice question where the user may select one of the available options but not multiple. AGE A question that receives the subject's age. DATE A question that receives a date.

(114) Follow up questions based on multiple choice questions: A multiple-choice question (e.g. CLICK-BOXES, SELECTMANY, SELECTMANYDENSE, SELECTONE, or any other multiple-choice question) may have follow-up questions (child nodes) that display in the user interface if one or more pre-specified particular answer choice options is selected by the user.

(115) For example, this question, "Do you have any of the following symptoms? Fever, shortness of breath, chills, headache" may have a follow-up question "How high is the fever?" if "fever" is one of the answer choices selected by the user.

(116) Advanced Report Generation

(117) Clinician- or Staff-Completed Questionnaires: Clinicians or staff may complete questionnaires, inputting information about a patient's health themselves in order to generate documentation. For example, a psychologist may have a lengthy questionnaire about a patient's psychological state, and this questionnaire may contain questions that the patient can answer (e.g., "Where were you born?") as well as questions that represent the psychologist's observations of the patient (e.g., "Affect: within normal limits, depressed, anxious . . . ") The psychologist may then complete the questionnaire during or after a patient interview, and a note or report may be generated from the questionnaire. In another example, a staff member may complete a questionnaire based on their interactions with the patient before, during, or after the appointment.

(118) Appointment Templates: A practice, institution, health system, or other organization may have different kinds of appointments. For example, a primary care clinic may have an annual wellness appointment, a follow up visit, or a problem visit. Or an endocrinology clinic may have diabetes follow up appointments and thyroid disease follow up appointments. It may be desirable to have clinicians, staff, and/or patients each complete one or more different questionnaires or forms before, during, or after an appointment of a particular type. Furthermore, the specific kinds of questionnaires or forms that each person should complete may vary depending on appointment type.

(119) A user interface may be implemented in which an appointment template is created to describe an appointment type with a name, and enable creation of a data structure that links a user (clinician, staff, patient, or other user) with a specific task (such as completing a questionnaire or form), and task details. If the task is completing a questionnaire or form, the exact questionnaire or form to be completed may be specified as the task details.

(120) Then when a patient's appointment is created in a user interface, it may be linked with an appointment type, where the list of appointment types is drawn from a backend database storing all of the appointment templates associated with that institution. Tagging an appointment with an appointment type may automatically assign the different users (clinician, staff, patient, other) with one or more tasks each.

(121) Combining Multiple Questionnaires: Multiple questionnaires may generate text and the text from multiple questionnaires may be combined into the one longer generated note or report.

(122) Comprehensive Digital Patient Intake

(123) Electronic health record integration for automated comprehensive patient intake: An integration with an existing electronic health record (EHR) may be implemented. Examples of existing electronic health records including eClinicalWorks, athena health, Epic, Cerner, Allscripts, PracticeFusion, and DrChrono. An EHR integration with a Cydoc application may involve a scheduling or appointments integration in which the Cydoc application queries information about which patients are scheduled for a particular day, including patient contact information such as name and phone number. The Cydoc application may then automatically send a patient one or more automated appointment sent reminders, via text message or email, with or without a secure link. This secure link may be unique to a particular practice or it may be unique to a particular patient. The

secure link may direct the patient to a responsive web application where the patient may complete a Smart Patient Intake Form or questionnaire, and/or input intake-related or clinical information such as name, date of birth, social security number, insurance card information, a photo or scan of the front or back of an insurance card, medications, allergies, past medical history, family history, social history, surgical history, and/or review of systems. The Cydoc application may then send information from the patient back into the EHR into relevant corresponding fields, for example by inserting a generated note into a note in the EHR, inserting a generated History of Present Illness into a note in the EHR, and/or by synchronizing specific information collected from the patient with corresponding section in the EHR—such as synchronizing past medical history with an EHR past medical history section.

(124) In another example, an EHR integration with a Cydoc application may involve the Cydoc application querying clinical information about a patient such as medications, allergies, past medical history, family history, social history, and/or surgical history, and using this queried information to populate a user interface, then requesting that the patient confirm, deny, or update the displayed information. In this way a patient may be shown the list of medications stored in the EHR within the Cydoc application interface, and the patient can specify if they are taking or not taking each displayed medication, as well as listing any new medications that they have started taking either over the counter or as prescribed by another physician who uses another EHR.

(125) Node Third-Party Attribute: Nodes may have a attribute that defines the node's conceptual relationship to a third-party software system, third-party application programming interface, or concept in third party documentation. The attribute may be called Third_Party_ID. The attribute may contain an alphanumeric string indicating a variable name, concept, unique ID, or other identifier of a concept present in a third-party system. This Third_Party_ID can enable implementation of code that will retrieve the user's response to this particular question and pass it along to a third-party application such an electronic health record. For example the Third_Party_ID may be a variable name in the third-party application like insuranceGroupNumber and this indicates that whatever response is given to this particular node should be passed to the third-party application as the value of the variable insuranceGroupNumber.

(126) FIG. **3** is a diagram of an example data structure for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure. FIG. **3** depicts example questions for chest pain and pain in general. Each box represents a node in the data structure. Each node includes a Node ID, which is an alphanumeric identifier that uniquely identifies the node. Each node has an associated response prompt (shown in the figure by "Question"), and an associated template sentence (shown in the figure by "TS"). The nodes can be linked in different ways; the links are represented as arrows. The linking of the nodes produces the data structure. The first chest pain question in the example is CHP0001 "Do you have chest pain?" If the response is yes, then the arrows to the child questions PAIN002, PAIN006, PEM0001, CHP0006, CHP0007, CHP0002, and other child questions may be traversed, and these child questions may be presented. These child questions may be follow-up question such as "Does the pain get better with sitting up and leaning forward?" or "On a scale of 1 to 10 how would you rate your pain?" Empty boxes with ellipses represent additional child questions not explicitly shown. The PEM questions, PEM0001, PEM0002, PEM0003, and PEM0004 represent pulmonary embolism nodes, with their question text and other content not explicitly shown. The link between the chest pain question CHP0001 and the pulmonary embolism question PEM0001 exemplifies how it is possible to connect data structures of different diseases or conditions to form a larger data structure. Note that it is possible to reach PAIN002, PAIN006 and other pain-related nodes from the PAIN001 node "Do you have any pain?" as well as the CHP0001 node "Do you have chest pain?" Thus, nodes can be linked in many different ways, and a single node may be used as part of questionnaires for many different diseases, symptoms, or conditions. The links, represented as arrows, are traversed according to the user's responses. There may be many different formats of the

response prompts (shown in the figure by "Question") or template sentences (shown in the figure by "TS"). Multiple different formats for the response prompts (questions) are shown, including yes or no (CHP0001, CHP0006, PAIN001), multiple choice (CHP0007, CHP0002), numerical (PAIN006), and body location (PAIN002) each of which may have a unique way of being displayed in a corresponding user interface.

(127) FIG. **4** is a diagram of the same example data structure shown in FIG. **3** for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure, with additional information added to emphasize the narrative construction. Specifically, a field labeled "Response" and highlighted in yellow has been added to nodes, containing an example user response for the nodes. For example the user has responded YES to CHP0001, which is shown as "Response: YES." This response causes the links to the child nodes to be traversed. The part of the data structure which defines what kind of response causes a traversal to other nodes is not explicitly shown. Based on the user's responses and the template sentences a raw narrative is constructed and shown in yellow as "Raw Generated Text Excerpt." The text is an excerpt because it does not include sentences corresponding to nodes that are part of the data structure but not shown in full detail in the figure. The generated text has been created by inserting the user's response into the blank marked with "RESPONSE" in the template sentence, or by choosing the correct template sentence corresponding to a Yes or No response for a Yes or No question. For example, the sentence "The patient has chest pain" is selected based on a YES response to "Do you have chest pain?"; the user's response "chest and jaw" is inserted into "The patient has pain in their RESPONSE" to create the sentence "The patient has pain in their chest and jaw"; the user's response "pressure, constriction" is inserted into "The pain feels like RESPONSE" to create the sentence "The pain feels like pressure and constriction." For multiple-choice questions, the template sentence may also include options that the user did not select, represented as NOTRESPONSE. Thus, if the user does not select "squeezing, tightness, burning" for CHP0007, a sentence "It does not feel like squeezing, tightness, or burning" may be generated from this node in addition to other sentences. The generated text is referred to as "raw" because it has not undergone any clean-up steps based on rules, machine learning techniques, or artificial intelligence techniques.

(128) FIG. **5** is another representation of an example data structure for constructing a narrative of an interaction with a subject and for presenting the narrative in accordance with embodiments of the present disclosure. Here, each row of the table corresponds to one node in the data structure, and each column of the table corresponds to a different attribute of that node. The node attributes (columns) include "Body System", which indicates which body system the node's question relates to. Body Systems shown include "CVRESP" as an example indicator for "cardiovascular and respiratory" and "MSK" as an example indicator for "musculoskeletal." The "Question Category" is the name of the disease, symptom, or condition that the node's question relates to, e.g. CHEST_PAIN, JOINT_PAIN, or PAIN. The "Question ID" is the alphanumeric ID that uniquely identifies the node. The "Question" is the text of the response prompt, which may be phrased as a question. The "Question Type" indicates a category for the "Question" which may determine how the response prompt is presented to the user in a user interface. For example, a CLICK-BOXES (multiple choice) question may be presented as the response prompt text e.g. "Do you have any of the following symptoms with your joint pain?" followed by individual clickable options for "rash," "redness," and "swelling." "Response to More Questions" (abbreviation for "Response Leading to More Questions") describes the nature of the user response that should trigger traversal to the child nodes. "Child Questions" is a list of the Question IDs for child nodes that should be traversed to if the user provides a response matching the description in the "Response to More Questions." "Template sentence" is a template sentence for questions that are not YES-NO questions. "YES: Template sentence" is a template sentence for a YES-NO question, and will become part of the generated note if the user inputs Yes to the corresponding question. "NO: Template sentence" is a

template sentence for a YES-NO question, and will become part of the generated note if the user inputs No to the corresponding question.

(129) FIGS. **6-67** are various screenshots of a system in accordance with embodiments of the present disclosure.

(130) FIG. **6** is a registration form that a user may fill out indicating personal information such as their first name, last name, email address, and whether they are a healthcare professional, patient, or administrator. The system may have a different user interface depending on whether the user is a healthcare professional, patient, or administrator.

(131) FIG. **7** is a login screen which enables the user to access the application. If any protected health data is stored, user access will comply with HIPAA and HITECH regulations including appropriate security measures, and only allowed users will be able to access protected health information. Multifactor authentication may be required—for example, after entering a username and password, a user may be required to enter a numeric code sent to their mobile device.

(132) FIG. **8** is an example of a landing page that enables a user to access different functionality of the system. The "New Note" box includes pinned note questionnaires that the user has chosen to pin, as well as recently used questionnaires. The user may click on a questionnaire name to begin filling out a note based on that questionnaire. The user may also browse through all questionnaires on a separate page, if they wish to select a questionnaire that is not shown on the landing page. "Open Recent" enables a user to open a recent note that they were working on. The names of recent notes are shown. If the user clicks on the name of a recent note, that note will be loaded in to the note user interface so that the user may continue working on it. "Create Template" enables a user to create a template or questionnaire for a note section, or create a template group. Different note sections can have custom templates, including the History of Present Illness, Review of Systems, and Physical Exam. A template group indicates a grouping of a History of Present Illness, Review of Systems, and/or Physical Exam template under a single name. The user can click on the elements of the Create Template box to be taken to an interface for creating a custom template.

(133) FIG. **9** is an example of creating a template group. The user can select one History of Present Illness template, one Physical Exam template, and one Review of Systems template which will be saved together under a group name. Note that there is a template option "Show all"; if "Show all" is selected then in the note user interface the user will be presented will all of the different specific options for that template. Thus, a user could for example pick "Chest Pain 3" for the History of Present Illness, "Inpatient Template 3" for the Physical Exam, and "Show All" for Review of Systems, in which case the template group would enable creation of a note interface based on "Chest Pain 3" and "Impatient Template 3"; when the user reached the Review of Systems section they would be presented with the different Review of Systems options to select from.

(134) FIG. **10** is an example of a view the user may see if they choose to browse all of their existing templates. Templates are organized according to note section. There is also a box for template groups. The user can pin or unpin templates. The user can use the Search functionality to search for a template using key words and/or the template name.

(135) FIG. **11** is an example of a view the user may see if they choose to browse all of their existing notes. On the left, the different months are shown, organized from most recent month to least recent month. If the user selects a month, such as "July 2020" shown in the figure, then a calendar-like organized pop out will display, showing the days of that month. Each day of the month includes a list of patient names and corresponding note names. The user can select a particular note (indicated by a patient name and note name) and load that note into the interface. On the right a preview of note information is shown. This may additionally include an excerpt from the generated note.

(136) FIG. **12** is an example of the first part of a History of Present Illness section in which the user selects diseases, symptoms, or conditions that are relevant for the visit. The diseases, symptoms, or conditions may be organized by body system as shown in this figure. In this figure, the user has

selected Chest Pain, Diabetes, and Joint Pain, which has caused these buttons to display in a different color and also to appear at the top of the page.

(137) FIG. **13** is an example of the first part of a History of Present Illness questionnaire for Chest Pain. This questionnaire is produced in the user interface based on the data structure of nodes connected by links. The first two questions shown are examples of multiple-choice questions. The third question is an example of a yes or no question. Notice also that at the top there are tabs for Chest Pain, Diabetes, and Joint Pain—one tab for each of the conditions that the user selected in the first part of the History of Present Illness. These can be thought of as the Chief Complaints.

(138) FIG. **14** is an example of an FH-POP question, or family history prepopulated question, which the user has not answered yet. When a node in the data structure is an FH-POP node, the user interface for that node is related to the user interface for the family history section, to facilitate sharing of the state and synchronization of information between the History of Present Illness family history information and the Family History section. When the user has not answered the family history question yet, as shown in this figure, only the names of the conditions are displayed along with a Yes or No option.

(139) FIG. **15** is an example of the same FH-POP question shown in FIG. **14**, except this time the user has filled in some responses. When the user selects Yes for a condition, as shown for "heart disease" then the interface will request specification of which family members have had this diagnosis and whether it was their cause of death. The user interface also provides space for free-text comments. If the user selects No, such as for "heart attack" and "high blood pressure" in this figure, then no further questions will be asked about those conditions.

(140) FIG. **16** is an example of a PMH-POP question, or past medical history prepopulated question, which the user had answered. A PMH-POP question enables sharing of state between the History of Present illness past medical history questions and the Past Medical History section of Patient History. The PMH-POP question enables the user to specify Yes or No for a particular list of conditions, shown as one condition per row. The user can also specify the Onset and put in free text Comments.

(141) FIG. **17** is an example of how the History of Present Illness section may rely on a data structure that includes many different diseases or conditions. The question "Do you exercise?" has been answered with "Yes" which has triggered the system to pose child questions from an exercise data structure. Thus, the chest pain data structure has made a reference to the exercise data structure; they can conceptually be thought of as part of one large data structure that covers many different medical conditions.

(142) FIG. **18** is an example of two LIST-TEXT questions in the History of Present Illness. The user interface for LIST-TEXT questions is a list. The user can delete elements from the list using the minus button and can add elements to the list with the plus button. Example text has been entered in to the list for each question.

(143) FIG. **19** is an example of some of the diabetes-related questions as part of the History of Present Illness section. The user has filled out responses to these questions.

(144) FIG. **20** when considered together with FIG. **19** exemplifies how the data structure may be traversed differently depending on how a user responds to questions. In FIG. **19** the user answered "No" to the question "Do you check your blood sugar?" and this caused no follow-up child questions to be asked. In FIG. **20** the user answered "Yes" to the question "Do you check your blood sugar?" and this caused multiple follow-up child questions to be asked, including "Have you had your blood sugar equipment checked to see if it works correctly?" and "Do you keep a blood sugar record book?" In this example the user has filled out responses to the follow-up child questions.

(145) FIG. **21** is an example of a Past Medical History section. In this system the Past Medical History section is a sub-tab of a Patient History section. In the Past Medical History the user can specify a patient's personal history of certain predefined conditions (listed here as Type II Diabetes,

Myocardial Infarction, and Hypertension). They can also enter history of custom conditions using a plus row option that is not explicitly shown.

(146) FIG. **22** is another example of a Past Medical History section. In this example, the user can specify a patient's personal history of predefined or custom conditions. For each condition the user can specify whether or not the patient has it (the first Yes vs No buttons), the Start Year of the condition, whether or not the condition has resolved, the End Year of the condition (if the condition has resolved), and comments.

(147) FIG. **23** is an example of a Surgical History section. In this system the Surgical History section is a sub-tab of a Patient History section. In the Surgical History section the user can specify previous procedures, their date, and comments.

(148) FIG. **24** is an example of a Medications section. In this system the Medications section is a sub-tab of a Patient History section. In the Medications section the user can specify medications according to their names, start date, schedule (i.e. how often they take it), dose, reason for taking (e.g. a particular disease), side effects if any, and free text comments.

(149) FIG. **25** is an example of an Allergies section. In this system the Allergies section is a sub-tab of a Patient History section. In the Allergies section the user can specify allergies according to the inciting agent (e.g. pollen, bees, peanuts), reaction (e.g. hives, itching, sneezing), and free-text comments.

(150) FIG. **26** is an example of a Social History section. In this system the Social History section is a sub-tab of a Patient History section. In the Social History section the user can specify various aspects of their social history. Social History may include substance use such as tobacco (including packs per day and total number of years), alcohol (including drinks per week and type of drinks), and recreational drugs (including their names and modes of delivery). The Social History may also include descriptions of living situation, employment, diet, and exercise.

(151) FIG. **27** is an example of a part of a Social History section for describing Tobacco use. In this example the user has selected "Yes" to indicate that the patient does use tobacco. Because the user selected "Yes" additional follow-up questions are posed, including the Packs/Day (filled in here as 2), the Number of Years (filled in here are 12), the products used (filled in here as cigarette and pipe), whether the patient is interested in quitting (filled in here as Yes), and whether the patient has tried to quite before (filled in here as Yes).

(152) FIG. **28** is an example of a part of a Social History section for describing Tobacco use. In this example the user has selected "In the Past" to indicate that the patient previously used tobacco but does not any more. Because the user selected "In the Past" additional follow-up questions are posed, including the Quit Year (the year in which the patient stopped using tobacco). In this example Packs/Day, Number of Years, and Products Used are filled out.

(153) FIG. **29** is an example of a part of a Social History section for describing Alcohol use. In this example the user has selected "Yes" to indicate that the patient does use alcohol. Because the user selected "Yes" additional follow-up questions are posed, including a summary of drinking habits in tabular form (filled in here as 2 glasses of wine and 1 tumbler of beer per week), whether the patient is interested in quitting (filled in here as "Maybe") and whether the patient has tried to quit before (filled in here as "No.")

(154) FIG. **30** is an example of a part of a Social History section for describing Alcohol use. In this example the user has selected "In the Past" to indicate that the patient previously used alcohol. Because the user selected "In the Past" additional follow-up questions are posed, including the Quit Year (the year in which the patient stopped using alcohol, filled in here as 2003). The interface also allows the user to specify the patient's previous drinking habits.

(155) FIG. **31** is an example of a Family History section. In this system the Family History section is a sub-tab of a Patient History section. In the Family History section the user can specify whether they have a family history of certain conditions which may be pre-defined, or custom. Custom family history conditions can be added using the plus button at the bottom that says "+ add family

history." Further details of the Family History interface are provided in FIGS. **14** and **15**.

(156) FIG. **32** is another example of a Family History section. In this interface, the user can specify whether the patient has a family history of any particular condition (in this example, "diabetes"). Because the user has selected "Yes" here for a patient having a family history of diabetes, the interface allows entering more detailed information including the family member or family members affected (in this example, "mother" and "father") and for each family member whether it was their cause of death. For "mother" the cause of death option has been selected "No" in this example prompting a follow up question of whether the mother is still living (filled out as "Yes" here). For "father" the cause of death option has been selected "Yes." A button "+ add family member" when clicked will allow the user to add additional family members who have diabetes. A button "+ add disease" will allow the user to add additional diseases found in the patient's family history.

(157) FIG. **33** is an example of the top part of a Review of Systems section in which the user has not yet selected any responses. Each body system is displayed on a card. Different symptoms related to that body system are displayed within the card, with a NO button and a YES button so that the user can indicate whether the symptom is occurring.

(158) FIG. **34** is an example of the top part of a Review of Systems section in which the user has selected responses. The No responses are shown in green because this indicates health, or the absence of a symptom; the Yes responses are shown in red because this indicates disease, or the presence of a symptom. The Yes and No buttons are shown on opposite sides of the word to minimize the risk of accidentally clicking the wrong response. The display is responsive so that when the screen changes sizes, a different number of blocks will be shown horizontally. On a mobile device one block will be shown at a time and the user can scroll down through all the blocks for all the body systems.

(159) FIG. **35** shows part of a Physical Exam section, specifically the vitals at the top, General, and Head, in which the user has not yet filled in responses. Vitals include blood pressure, heart rate, respiratory rate (RR), temperature, and oxygen saturation. General includes the patient's overall appearance. Head includes descriptions of the patient's head. The buttons that has the upside-down "A" on it (the "for all" symbol in mathematics) represents a button which when clicked will automatically select all of the buttons in its row. Which buttons appear together in a row has been strategically chosen to reflect the way that clinicians perform physical examinations and which findings tend to be observed together. The strategic grouping of particular physical exam findings along with the "for all" button is an example of a user interface design choice intended to accelerate entry of information.

(160) FIG. **36** shows part of a Physical Exam section, specifically the vitals, General, and Head, in which the user has filled in responses. The vital signs have been filled in by entering numbers. The General and Head sections have been filled in by clicking buttons. The "for all" button was used to enable clicking all buttons in one row together.

(161) FIG. **37** shows part of a Physical Exam section, specifically the section for the Eyes, in which the user has filled in responses. Normal findings are shown at the top while abnormal findings are shown at the bottom. When normal findings are clicked they turn green. When abnormal findings are clicked they turn red. This section exemplifies the Left-Right button functionality. In the Left-Right button functionality, when a user clicks on a button for a finding that may occur on the left and/or on the right, an L button shows up on the left and an R button shows up on the right. The user can select L to indicate that the finding is seen on the Left, and they can select R to indicate that the finding is seen on the Right. If they leave L unselected it implies that the finding is not seen on the Left. If they leave R unselected it implies that the finding is not seen on the Right. In the figure, a-v nicking is seen on the left, bruising is seen on the right, and watery discharge is seen on both the left and the right. At the bottom, there is a drop-down menu from which the user can select rarer findings; in this example they have selected blepharitis, a-v nicking, and bruising. When the

user selected these findings from the drop-down menu they appeared as buttons with the Left-Right functionality. If the user wishes to remove these findings, they can click the "x" in the drop-down menu next to the finding name.

(162) FIG. **38** shows part of a Physical Exam section, specifically the section for the Ears.

(163) FIG. **39** shows part of a Physical Exam section, specifically the sections for the Nose and Throat.

(164) FIG. **40** shows part of a Physical Exam section, specifically the section for the Neck. Here, the "for all" button has been used to select everything in the group "supple, no thyromegaly, no lymphadenopathy, trachea midline."

(165) FIG. **41** shows part of a Physical Exam section, specifically the section for the Neck. Here, the user has selected some normal findings and one abnormal finding from the drop-down menu, "shotty lymph nodes."

(166) FIG. **42** shows part of a Physical Exam section, specifically the section for the lungs (Pulmonary). The Pulmonary section includes a widget for lung sounds which is organized with the left upper lobe, lingula, and left lower lobe on the left, and the right upper lobe, right middle lobe, and right lower lobe on the right, following the anatomical layout of these lung locations when facing a patient's back. For each lung location the user can select wheezes, rales, or rhonchi as the sound, or additional sounds using the plus button.

(167) FIG. **43** shows part of a Physical Exam section, specifically the sections for Kidney and Cardiac.

(168) FIG. **44** shows part of a Physical Exam section, specifically examples of the Cardiac Murmurs widget. There are two examples of the widget shown, one where "systolic" is selected and the other where "diastolic" is selected. When "systolic" is selected, the lower section of the widget displays different options than when "diastolic" is selected. The upper section of the widget always shows the same options for describing the heart murmur: crescendo/decrescendo/crescendo-decrescendo, heart best at the RUSB/LUSB/RLSB/LLSB/apex (RUSB=right upper sternal border, LUSB=left upper sternal border, RLSB=right lower sternal border, LLSB=left lower sternal border), intensity in range 1-5, pitch low/medium/high, and quality blowing/harsh/rumbling/whooshing/rasping/musical. The lower section of the widget relates to specific murmurs and changes depending on whether systolic or diastolic is selected. When systolic is selected, various names and properties of systolic murmurs are shown in the lower section of the widget. When diastolic is selected, various names and properties of diastolic murmurs are shown in the lower section of the widget. The names and properties of murmurs are grouped according to medical knowledge. For example, an aortic stenosis murmur is best heard at the right upper sternal border and radiates to the carotid arteries, and so the button for "aortic stenosis" occurs on the same line as "best heard at RUSB" and "radiation to carotids." There is some redundancy built in to the widget's appearance, but there is no redundancy in the underlying state (the underlying data representation), which means that if the user selects "RUSB" in the "Heart best at" part of the upper section, then the button for "best heard at RUSB" will also light up in the lower section. As another example, if the user selects "best heard at LLSB" in the lower section, then "LLSB" will also light up in the upper section. The widget is designed and arranged to prompt the user to remember what murmur properties are related to what specific types of murmurs.

(169) FIG. **45** shows part of a Physical Exam section, specifically the section for Pulses. If the user clicks on "add pulses" they will be shown a pulses widget that enables them to enter abnormal pulses.

(170) FIG. **46** shows part of a Physical Exam section, specifically the section for Pulses. Here the user has indicated "normal radial," "normal ulnar," and "normal dorsalis pedis" pulses, and they have also clicked on "add pulses" so that the pulses widget is displayed. Within this pulses widget, "brachial," "right," and "4+ bounding" have been selected to indicate that the patient has a 4+ right brachial pulse on physical exam. More instantiations of the pulses widgets can be added (to specify

more pulses) by clicking on the "add abnormal pulses" button.

(171) FIG. **47** shows part of a Physical Exam section, specifically the section Gastrointestinal, in which all normal options have been selected using the "for all" buttons, thus requiring only 4 clicks to select all these normal findings. Notice that the normal buttons are green when clicked.

(172) FIG. **48** shows part of a Physical Exam section, specifically the section Gastrointestinal, in which several abnormal options have been selected. Notice that the abnormal buttons are red when clicked. Additionally, the widget for gastrointestinal quadrants has been used to indicate abnormal findings in particular gastrointestinal quadrants. The widget is organized following the quadrants as seen when viewing a patient from the front, with the Right Upper Quadrant shown on the upper left (when viewing a patient from the front the clinician's left is the patient's right), and the Left Lower Quadrant shown on the bottom right. The user can select tenderness, rebound, and/or guarding for each quadrant.

(173) FIG. **49** shows part of a Physical Exam section, specifically the sections Extremities and Tendon Reflexes. In Tendon Reflexes there is a widget that can be used to specify an abnormal tendon reflex according to the location (biceps, brachioradialis, triceps, patellar, ankle jerk, plantar), side (right, left), and reflex strength (0, 1, 2, 3, 4). The user can add multiple abnormal reflexes by clicking on "add reflexes" repeatedly to pop up multiple copies of the widget.

(174) FIG. **50** shows part of a Physical Exam section, specifically the sections Skin and Neuro Additional.

(175) FIG. **51** shows part of a Discussion & Plan section, specifically the Differential Diagnosis. There are tabs for each of the Chief Complaints selected in the History of Present Illness section, in this example Joint Pain, Diabetes, and Chest Pain. For each Chief Complaint separately the user can enter a differential diagnosis. The user can enter as many differential diagnoses as they wish by clicking the "+ add diagnosis" button as many times as is needed.

(176) FIG. **52** shows part of a Discussion & Plan section, specifically the Prescriptions. For each Chief Complaint separately the user can enter Prescriptions, if any. In the example the user has entered aspirin 81 mg tablet. The user can enter as many medications as they wish by clicking the "+ add prescription" button.

(177) FIG. **53** shows part of a Discussion & Plan section, specifically Procedures and Services. For each Chief Complaint separately the user can enter Procedures and Services. Multiple Procedures and Services can be entered. In this example electrocardiogram and routine chest x-ray have been filled in along with "When" and "Comments." The user can add as many Procedures and Services as they wish by clicking the "+ add procedure or service" button.

(178) FIG. **54** shows part of a Discussion & Plan section, specifically Referrals and Help Improve Cydoc. In this example, Cardiology and Cardiothoracic Surgery have been entered as referrals. The user can add as many referrals as they wish by clicking the "+ add referral" button. The Help Improve Cydoc section is a section in which questions are posed to the user that will facilitate building artificial intelligence applications on the collected data. The questions included in this example are "How sick is the patient?" to enable building an artificial intelligence model to predict a numerical score for how sick the patient is; "Will the patient be sent to the emergency department?" to enable building an artificial intelligence model to predict whether the patient will need to go to the emergency department; and "Will the patient be admitted to the hospital?" to enable predicting whether the patent will need to be admitted to the hospital.

(179) FIG. **55** shows part of a user interface for creating a custom History of Present Illness template (a custom HPI knowledge graph for a particular disease or condition of interest). On this page the user can enter a title for the custom History of Present Illness template.

(180) FIG. **56** shows part of a user interface for creating a custom History of Present Illness template. The user can specify a Body System, in this example Cardiovascular/Hematologic. The user can specify a Disease, in this case "Heart Disease." While in this example the template name is "Heart disease" and disease name is also "Heart Disease", note that they do not have to be the

same. For example the template name might be "Heart Disease Inpatient Template" and the disease name "Heart Disease."

(181) FIG. **57** shows part of a user interface for creating a custom History of Present Illness template. Here the user has written one question: "Do you have heart disease?" They have specified that this is a "Yes/No" question and so two template sentence boxes have appeared: one for "If Yes" and the other for "If No." The template sentence for "If Yes" has been filled in with "The patient has heart disease" in this example, while the template sentence for "If No" has been filled in with "The patient does not have heart disease." When a note is generated based off of this template, the template sentence for "If Yes" will be used when the answer to this question is Yes, while the template sentence for "If No" will be used when the answer to this question is No. Additionally, a button for "+Add follow-up question" can be seen; if this button is clicked there will be an option to add a follow-up question to this question (corresponding to a child node in the underlying knowledge graph data structure). A button for "Connect to other graphs" can also be seen, which enables connecting this question to another pre-existing collection of questions (corresponding to adding an edge between this question node and some other node in an existing knowledge graph). At the bottom of this figure, blank slots for five more questions can be seen, followed by an "+Add question" button which enables adding yet more question slots.

(182) FIG. **58** shows part of a user interface for creating a custom History of Present Illness template. Here the user has written two follow-up questions for the question "Do you have heart disease?" One follow-up question is "How many years have you had heart disease?" and the selected question type is "Age or Duration" which when this template is used will cause the "Age or Duration" interface to appear below the question text so that the user can quickly input an amount of time. The user has written in template sentence (Sentence to Generate) as "The patient has had heart disease for RESPONSE" which means that if the user enters "5 years" when this template is used, the sentence that is generated from this question/answer/template sentence will be "The patient has had heart disease for 5 years." The other follow-up question that has been added is "Have you experienced any chest pain?" and the selected question type is Yes/No. Because this is a Yes/No question it needs two template sentences, one for a Yes response ("The patient has experienced chest pain") and one for a No response ("The patient has not experienced chest pain").

(183) FIG. **59** shows part of a user interface for creating a custom History of Present Illness template. Here the user has written a Multiple Selection question "Do you have any of the following symptoms" with the options headache, loss of appetite, dizziness, and weakness. The "add option" button enables the user to continue adding options. The template sentence in this example is "The patient has RESPONSE" so for example if the user selected "headache, dizziness" when using this template, the generated sentence would be "The patient has headache and dizziness."

(184) FIG. **60** shows part of a user interface for creating a custom History of Present Illness template. Here the user has written a Short Text response prompt "Please describe what happened when you fell." (Note that the phrase "response prompt" encompasses questions as well as other phrasings that request information.) The template sentence that the user has written here is "The patient describes their fall as RESPONSE."

(185) FIG. **61** shows part of a user interface for creating a custom History of Present Illness template. Here the user has written a List question "What do you normally eat for breakfast?" When this template is used to create a note, this List question will be shown with the List interface which enables the user to type into various boxes to create a list. The template sentence that the user has written here is "The patient normally eats RESPONSE for breakfast."

(186) FIG. **62** shows part of a user interface for creating a custom History of Present Illness template. Here the user has written a Body Location question "Where is the numbness?" When this template is used to create a note, this Body Location question will be shown with the Body Location interface which enables to user to click on various body location options to specify the

body location. The template sentence that the user has written here is "The numbness is in the RESPONSE." Overall, the user can select from many different question types in the interface when creating a template, including Yes/No, Multiple Selection, Short Text, Age or Duration, Number, List, Body Location, Past Medical History (sync), Family History (sync), Medications (sync), and Past Surgical History (sync). The question types listed here next to "(sync)" are BLANK or POP questions described earlier as special question types that enable synchronization of information between the History of Present Illness section and a corresponding Patient History section. For example, the Past Medical History (sync) option in the Create HPI Template interface creates a MEDS-BLANK question (if no specific medication options are entered), or a MEDS-POP question (if specific medication options are entered). Also note that the user can specify what kind of response should trigger asking child questions, and the user can re-order questions and change the relationships between questions, for example by dragging and dropping questions in the user interface.

(187) FIG. **63** shows a user interface for creating a custom Physical Exam template. On the left, the Template Name area allows the user to type in a template name under which this Physical Exam template will be saved. The interface includes multiple cards, where each card may hold a topically related group of physical exam findings. The top card has the word "Body System" at the top which represents a place where the user can type in the relevant body system or other relevant descriptor for this group of physical exam findings. There are 3 lines shown with a drop-down for Line Type that enable the user to specify a line type, which can be Buttons, Dropdown, or Widget. The "Add Line" button at the bottom of each card enables the user to add more lines, and the "x" on the right enables the user to delete lines. On the bottom card the word "Eyes" has been filled in as the card title. The top row Line Type has been selected as "Buttons." The user has checked the "Select All" box which creates the select all button that will enable selecting all options on this row by clicking the button at the front with the "for all" symbol on it. The user has selected the "Normal" radio button which means that the buttons on this line will be green when clicked and represent normal findings. The user has typed in button text of "nontender" and "nondistended"; they can add more button text options using the plus button, and each piece of button text will be used to generate a separate button in the Physical Exam interface. The second row Line Type has been selected as "Buttons." The user has checked the "Left/Right" box which means that buttons on this row will be "left right buttons" which when clicked have L and R pop-out buttons on the side that enable the user to specify whether the finding is on the right, the left, or both sides. The user has clicked the "Abnormal" radio button which means that the buttons on this line will be red when clicked and represent abnormal findings. The user has typed in button text of "tender" and "distended" which means that in the Physical Exam interface these will show up as one button for "tender" and another button for "distended." On the third line, the Line Type has been selected as "Dropdown" and the user has typed in dropdown text options of "arcus senilis," "astigmatism," and "blepharitis" which means that these options will show up in a dropdown menu. The user can add more options to the Dropdown by clicking the plus button. The user can also specify if the dropdown needs Left/Right functionality; if this is chosen then when the Dropdown is used, clicking an item in the dropdown will cause a "left right button" to show up with that item's text on it so that the user can specify if it shows up on the left, right, or both sides. The final row has a Line Type of "Widget" which means another dropdown appears for selecting the widget. Widget options may include a tendon reflexes widget, pulses widget, cardiac murmurs widget, lung sounds widget, abdomen widget, and/or skin widget. The "Add Card" button at the bottom enables the user to add more cards.

(188) FIG. **64** shows an example illustrating a relationship between response prompt nodes (Question Nodes) and descriptive nodes (Category Nodes). In this example, the Question Nodes are shown as circles and the Category Nodes are shown as squares. The Question Nodes are connected to one another and each Question Node has an attribute ID (specifying the identity of the node),

Category (specifying the disease category of the node), and Author (specifying the author of the node). One Category Node has been created for each value taken on by the Category attribute of the Question Nodes, meaning that in this example there are three Category Nodes: CHEST_PAIN, PAIN, and ANXIETY. Furthermore, the Category Nodes have been connected to each other by edges according to the connectivity of the Question Nodes. Because a Question Node with Category CHEST_PAIN has a child node with Category PAIN, the Category Node CHEST_PAIN has a child Category Node PAIN. Because a Question Node with Category CHEST_PAIN has a child node with Category ANXIETY, the Category Node CHEST_PAIN has a child Category Node ANXIETY. Thus, the Category Node connectivity represents a summary of the Question Node Category attribute connectivity. Notice that in this example there are no connections (edges) between the Question Nodes and the Category Nodes.

(189) FIG. **65** shows an example illustrating a relationship between response prompt nodes (Question Nodes) and additional nodes describing the node author (Author Nodes or Doctor Nodes). In this example, the Question Nodes are shown as circles and the Doctor Nodes are shown as squares. Each Doctor Node has a connection (edge) to the root node of each Question Node subgraph for which the Author attribute of the Doctor Node matches the Author attribute of the Question Node.

(190) FIG. **66** shows an example illustrating a relationship between response prompt nodes (Question Nodes) shown as circles and descriptive nodes (Category Nodes) shown as squares. Similar to the example in FIG. **64**, the connectivity of the Category Nodes is determined by the connectivity of the Question Nodes and the Category attribute of the Question Nodes.

(191) FIG. **67** shows an example illustrating a relationship between response prompt nodes (Question Nodes) shown as circles and additional nodes describing the node author (Author Nodes or Doctor Nodes) shown as squares. Similar to the example in FIG. **65**, Doctor Nodes are connected to Question Nodes for which the value of the Author attribute in the Question Node matches the value of the Author attribute in the Doctor Node.

(192) FIG. **68** illustrates a screenshot of an example depicting how questions may be displayed by a topic area. For example, all questions related to "Chest Pain" may be displayed together as shown in this figure.

(193) FIG. **69** illustrates a depiction of print or a display of how a QR code may be displayed that a patient can scan in order to access a questionnaire specific to a practice.

(194) FIG. **70** illustrates a screenshot of an example of how a custom list of questionnaire topics may be pinned by practice. Here, questionnaire topics are shown, including Annual Physical Exam, High Blood Pressure, and Diabetes. This is an example of custom questionnaire topics selected for a specific family medicine practice and pinned to the user interface. The questionnaire topics shown in the bubbles could change to be entirely different for a different kind of practice.

(195) FIG. **71** illustrates a flow diagram of an example method of how a patient-questionnaire matching algorithm may be applied to practice information and/or patient information in order to output one or more questionnaire topics specific to the practice and/or patient information provided.

(196) Patient-questionnaire matching with artificial intelligence and machine learning: Artificial intelligence may be implemented for patient-questionnaire matching. Patient-questionnaire matching may be defined as the process of eliciting information from a patient, then selecting one or more preexisting questionnaire topics that align with the patient's visit reasons or chief complaints. The term "patient" here may refer to an actual patient or to any subject or user.

(197) In one implementation a method may be developed to predict questionnaire topics based on the practice information **201**. Practice information **201** may include specialty, past history of questionnaire topics used at that practice, or data for any patients seen at that practice. This method may be rule based and leverage the most commonly requested topics at that practice, determined via a calculation of the number of times each topic has been requested at that practice previously.

Or this method may use machine learning to use practice information as input and predict what questionnaire topics to display as output.

(198) In another implementation a method may be developed to predict questionnaire topics based on a patient's information **202**. This method may be rule based and use co-occurrence statistics between topics, to understand which topics co-occur most frequently with other topics and display commonly co-occurring topics as follow up after the patient has entered one or more topics. Or this method may use machine learning to use a patient's information to predict the next questionnaire topic(s). Patient information **202** may include demographics, past medical history, medications, allergies, surgical history, family history, responses to previous questions, or previously entered topic(s).

(199) In another implementation a method may be developed that takes as input practice information **201** and patient information **202** in order predict questionnaire topic(s).

(200) A patient-questionnaire matching algorithm **203** may be implemented leveraging one or more of the following methods: rule based, summary statistics, machine learning, neural networks, a Transformer neural network architecture, and/or a language model.

(201) The output of the patient-questionnaire matching algorithm **203** may be questionnaire topics **204** indicating one or more questionnaire topics specific to the practice and/or patient whose information was provided as input.

(202) FIG. **72** illustrates a flow diagram of an example method of how a language model (LM) may be used to construct a knowledge graph data structure. In the first step **205** an LM is prompted to provide a list of questions, then in the second step **206** to provide one or more template sentence(s) for each question. Additional node attributes may be obtained through the LM or user input in the third step **207**. The knowledge graph data structure is then constructed in the fourth step **208**, and may be submitted to a human expert for editing in the fifth step **209**.

(203) Language models for history taking: A language model (LM) may be used to construct the knowledge graph data structure in which nodes represent questions.

(204) In the first step **205**, to obtain a list of questions for a particular topic or patient, a language model may be prompted with a prompt such as: What are the top 10 questions to ask a patient with a headache? What are the top 5 questions a physician should ask a patient presenting to clinic with complaints of stomach pain? What questions should be part of history-taking when a patient comes to a doctor's office for a diabetes follow up visit?

(205) LM prompts to elicit lists of history-taking questions may include information about the number of history-taking questions to generate; the patient's age, past medical history, or other medical information; the specialty of the practice; and/or the patient's chief complaint(s). The prompts may also include information specifying the format of the answer, such as specifying that each output question should appear on a new line.

(206) In a second step **206**, an LM may be used to craft one or more template sentences for each question. An example prompt for the LM could be, "Generate a template sentence corresponding to the following question: question text" where "question text" is replaced by the actual question text. Alternatively, few-shot learning may be employed in which the LM is presented with examples of question-template sentence pairs, before being prompted to supply a template sentence for a new question, e.g. using this format: Question: Text of question 1 Template Sentence: Template sentence corresponding to question 1 Question: Text of question 2 Template Sentence: Template sentence corresponding to question 2 . . . Question: Text of question N Template Sentence: Template sentence corresponding to question N Question: Text of the newly generated question Template Sentence:

(207) The LM will thus be prompted to fill in the text for the final template sentence corresponding to the newly generated question.

(208) In a third step **207** Additional node attributes may be elicited from user input such as on a field-by-field basis through a form-like user interface. Additional node attributes may also be

elicited from the LM using a prompt engineering strategy that may or may not include few shot learning with examples drawn from a preexisting knowledge graph or questionnaire dataset.

(209) In a fourth step **208** a knowledge graph data structure may be constructed.

(210) In a fifth step **209**, a human oversight workflow may be implemented in which questions, template sentences, or data structures generated in whole or in part by an LM are sent via email, text message, web portal, or another form of electronic communication to an expert human user. The expert user may then review the questions, template sentences, or data structures and submit approvals, rejections, edits, or comments. In this way, expert human oversight can be incorporated to ensure that questions asked are reasonable, and that template sentences are factually correct relative to the questions. Rules or machine learning may also be leveraged to ensure template sentences are factually correct relative to the questions.

(211) FIG. **73** illustrates an implementation of a user interface for a SELECTMANY question, a SELECTMANYDENSE question, and a SELECTONE question. SELECTMANY, SELECTMANYDENSE, and SELECTONE are all multiple-choice questions. In SELECTMANY, a user may select no answer choices, one answer choice, or multiple answer choices. Each answer choice is shown with a yes button and a no button. For each answer choice, the yes button, or the no button, or both, or neither may be selected. In SELECTMANYDENSE, each answer choice is shown in its own button which may be selected to indicate yes, or deselected to indicate no or unanswered. A user may select no answer choices, one answer choice, or multiple answer choices. In SELECTONE, each answer choice is shown in its own button. A user may select no answer choices or exactly one answer choice.

(212) The present subject matter may be a system, a method, and/or a computer program product. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present subject matter.

(213) The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a RAM, a ROM, an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

(214) Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network, or Near Field Communication. The network may comprise copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device.

(215) Computer readable program instructions for carrying out operations of the present subject

matter may be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++, Javascript or the like, and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present subject matter.

(216) Aspects of the present subject matter are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the subject matter. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

(217) These computer readable program instructions may be provided to a processor of a computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

(218) The computer readable program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

(219) The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present subject matter. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer

instructions.

(220) While the embodiments have been described in connection with the various embodiments of the various figures, it is to be understood that other similar embodiments may be used, or modifications and additions may be made to the described embodiment for performing the same function without deviating therefrom. Therefore, the disclosed embodiments should not be limited to any single embodiment, but rather should be construed in breadth and scope in accordance with the appended claims.

Claims

1. A method comprising: at a computing device comprising at least one processor and memory: receiving one or more response prompts; constructing a data structure including one or more response prompt nodes, wherein the data structure is associated with a topic, wherein each response prompt node is associated with a response prompt, one or more template sentences, and one or more traversal criteria, wherein the response prompt nodes are ordered, wherein the response prompt nodes are linked by edges that are traversable based on a response to a response prompt at the respective node according to one or more traversal criteria; providing a user interface configured to display one or more response prompts, and display one or more additional response prompts according to one or more traversal criteria of one or more response prompt nodes; and providing a narrative build manager configured to: construct text for each response prompt node via insertion of the response into the template sentence, or by using the response to select from a set of template sentences; aggregate the text by traversing the nodes according to their connectivity via edges and traversal criteria; and present, via the user interface, a narrative of an interaction with a subject including the aggregated text.

2. The method of claim 1, wherein traversal criteria are defined within the response prompt text or within a response prompt node attribute, wherein one or more response prompt nodes is associated with a traversal criterion that is one of: traversing an edge after a yes or no response prompt is answered with "yes"; traversing an edge after a yes or no response prompt is answered with "no"; traversing an edge after a multiple-choice response prompt is answered with any of a pre-specified subset of the available answer choices.

3. The method of claim 1, wherein the response prompts each comprise one of a question, statement requesting information, or multiple-choice prompt.

4. The method of claim 1, wherein each template sentence is a grammatically complete sentence, a sentence fragment, or a sentence with a placeholder into which a response to a response prompt may be inserted.

5. The method of claim 1, wherein one or more response prompts comprises a request for health-related information about the subject; wherein one or more response prompts is related to any specialty or subspecialty within medicine, surgery, veterinary medicine, social work, psychology, physical therapy, occupational therapy, chiropractic, optometry, or any other field in which any patient of any species has a physical, mental, or social issue that can be evaluated through structured questioning; wherein the data structure is used to represent a questionnaire completed by a patient, patient caregiver, notetaker, clinician, or healthcare staff member; wherein a patient who completes a questionnaire provides responses based on their own health; wherein a patient caregiver, notetaker, clinician, or healthcare staff member who completes a questionnaire provides responses based on a patient's health.

6. The method of claim 1, wherein each response prompt node is associated with a display type, and each response prompt is displayed via a user interface that is customized according to the response prompt node's display type.

7. The method of claim 6, wherein the display type may be one of yes or no, multiple choice, text, list, number, time, body location, age, date, sliding scale, SELECTONE, SELECTMANYDENSE,

or SELECTMANY; wherein SELECTONE and SELECTMANYDENSE are any multiple-choice question types that provide in the user interface a single button for each multiple-choice answer choice that may be clicked to indicate yes, or unclicked to indicate no or unanswered; wherein a user may select no answer choices or exactly one answer choice for a SELECTONE question; wherein a user may select no answer choices, one answer choice, or multiple answer choices for a SELECTMANYDENSE question; wherein SELECTMANY is any multiple-choice multiple-select question type that provides in the user interface a yes button and a no button for each answer choice, wherein the user is permitted to select one, both, or neither of the buttons for each answer choice.

8. The method of claim 6, wherein the display type may be one of PMH-BLANK, MEDS-BLANK, FH-BLANK, PSH-BLANK, PMH-POP, MEDS-POP, FH-POP, or PSH-POP; wherein the display type prefix PMH indicates the response prompt is related to the subject's past medical history, the prefix MEDS indicates the response prompt is related to the subject's medications, the prefix FH indicates the response prompt is related to the subject's family history, and the prefix PSH indicates the response prompt is related to the subject's surgical history; and wherein the display type suffix BLANK indicates that the response prompt is open-ended and the user may provide any response in the user interface, while the display type suffix POP indicates a multiple-choice question in which a predetermined list of answer choice options will be displayed to the user in the user interface and they may select one or more answer choices from this predetermined list.

9. The method of claim 1, wherein any responses to any response prompts related to a patient's history of present illness, that are also related to the subject's patient history, are stored in the same part of the system's state as the data for independent user interface sections for patient history, to enable synchronization of data between the history of present illness and the sections for patient history, where patient history refers to medication usage, allergies, family health history, past medical history, surgical history, or social history.

10. The method of claim 1, further comprising providing a user interface to facilitate construction of the data structure; wherein the user interface includes at least one text box for entering a response prompt and at least one text box for entering a template sentence; wherein receiving one or more response prompts at the computing device comprises receiving user input of one or more response prompts.

11. The method of claim 1, wherein the response prompt nodes include a parent node and two or more child nodes that are each linked to the parent node, and wherein the links between the parent node and the child nodes are traversable based on a response to a response prompt at the parent node, and wherein the narrative build manager is configured to: receive a response to the response prompt at the parent node; use the response to the response prompt at the parent node to traverse a link or links to one or more of the child nodes; receive a response to the response prompt at one or more of the child nodes; and construct a narrative based on the responses to the response prompts for the parent node or one or more of the child nodes.

12. The method of claim 1, further comprising receiving, via a photograph or scan or digitization of a paper form, user input of the one or more responses, and transforming the digital data of the paper form into structured electronic data using artificial intelligence.

13. The method of claim 1, further comprising: receiving a specification for a predictive model including specification of the model type as regression, neural network, or another machine learning method; training and evaluating the performance of the specified predictive model based in whole or in part on received responses to one or more response prompts; and producing predictive model output based on one or more received responses to one or more response prompts.

14. The method of claim 1, further comprising, at the computing device: constructing a plurality of data structures each corresponding to a different topic or author, wherein each data structure includes an author node, a topic node, and a plurality of response prompt nodes; wherein each author node is linked via an edge to each response prompt node created by that author, and wherein

each topic node is linked via an edge to each response prompt node of that topic.

15. The method of claim 1, further comprising displaying the response prompts in a user interface according to topic, wherein all response prompts related to a particular topic are displayed one after another in a sequential manner, or are displayed together on the same page of a user interface.

16. The method of claim 1, further comprising providing a user interface that displays a QR code or link, wherein a user may scan the QR code or click the link in order to access a user interface that displays response prompts, wherein the QR code or link is specific to a particular medical practice, organization, entity, or individual.

17. The method of claim 1, further comprising creation of a data structure topics list, wherein the list contains the topics of one or more data structures pertinent to a medical practice, organization, entity, or individual.

18. The method of claim 1, wherein an appointment template is defined to specify a name of an appointment type and one or more topics for that appointment type, wherein each topic is associated with a data structure.

19. The method of claim 1, wherein each node is associated with one or more attributes that define the node's relationship to a third-party software system, third-party application programming interface, or concept or variable in third party software code or documentation; wherein the response to one or more response prompts is sent to a third-party software application via an application programming interface; wherein the third-party software application may be an electronic health record.

20. The method of claim 1, further comprising: collecting input data about a patient, collecting input data about a medical practice, or collecting input data about a patient and a medical practice; and processing the input data using a rule-based system, a machine learning model, a neural network, or a language model to produce an output that includes one or more data structure topics.

21. The method of claim 1, wherein a unique numerical order is assigned to each edge, and a separate unique numerical order is assigned to each node.

22. The method of claim 21, wherein the node ordering is used to determine the order that response prompts are displayed in a user interface, and the edge ordering is used to assemble the narrative.

23. A method comprising: at a computing device comprising at least one processor and memory: constructing a data structure including one or more response prompt nodes, wherein each node is associated with a response prompt and one or more template sentences, wherein the nodes are linked by edges, wherein one or more response prompts is obtained by prompting a language model to produce a response prompt, wherein one or more template sentences is obtained by prompting a language model to produce a template sentence for a response prompt; and providing a narrative build manager configured to: construct text for each response prompt node via insertion of the response into the template sentence, or by using the response to select from a set of template sentences; aggregate the text by traversing the nodes according to the connectivity defined by the edges; and present, via the user interface, a narrative of interaction with the subject including the aggregated text.

24. The method of claim 23, wherein a few-shot learning prompting strategy is used to prompt the language model.

25. The method of claim 23, wherein a user interface displays the constructed data structure to a human expert and receives feedback from the human expert in the form of deletions or edits to any part of the constructed data structure.

26. The method of claim 23, wherein rules or artificial intelligence is used to check whether template sentences are factually correct relative to their corresponding response prompts.

27. A method comprising: at a computing device comprising at least one processor and memory: rendering a user interface for a physical examination section, which includes any of the following user interface design elements: a "for all" button at the beginning of a row of buttons which if selected will cause all buttons in that row to select simultaneously; display of related physical

examination findings spatially close to one another in the user interface, for example with related physical examination findings all appearing as buttons in the same row; a "left-right" button which if selected will display another adjacent button on the left and another adjacent button on the right for the purpose of indicating which side(s) of the body a finding appears on; a lung sounds widget which is organized with six panels, one panel for each lobe of the lung, and within each panel displaying buttons for lung sounds such as wheezes, rales, or rhonchi; an abdominal exam widget which is organized with 4 panels for the 4 quadrants of the abdomen or 9 panels for the 9 sections of the abdomen, and within each panel displaying buttons for abdominal findings such as tenderness, rebounding, or guarding; a pulses widget which is organized to allow the user to select a pulse location (such as brachial, radial, ulnar, or dorsalis pedis), a pulse side (right or left), and a pulse strength (such as 0, 1+, 2+, 3+, 4+); and a reflexes widget which is organized to allow the user to select a reflex location (such as biceps, brachioradialis, triceps, patellar, ankle jerk, plantar), a reflex side (right or left), and a reflex strength (such as 0, 1+, 2+, 3+, 4+).