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(54) **RECOGNIZING USERS WITH MOBILE APPLICATION ACCESS PATTERNS LEARNED FROM DYNAMIC DATA**

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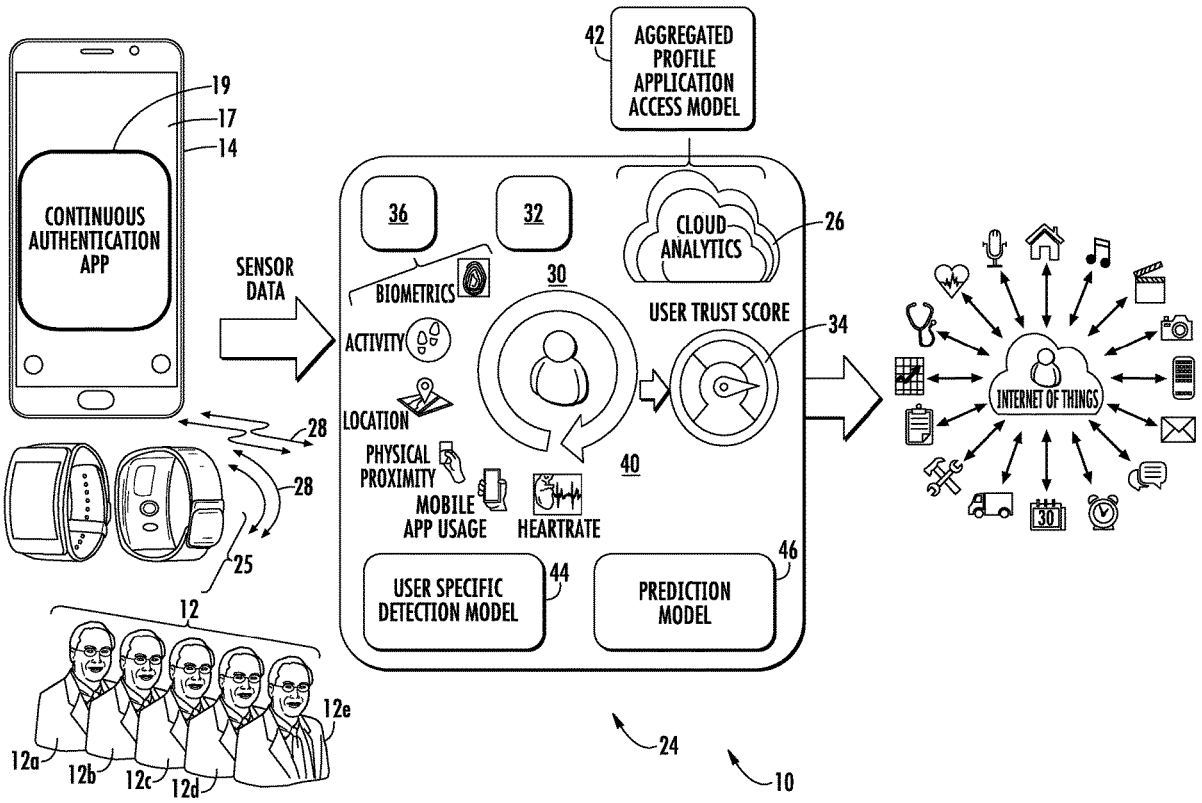
(57) **ABSTRACT**

A method of continuous user authentication on a mobile device including: establishing a baseline model generated based on acquiring dynamic data associated with the mobile device, deploying at least one of a training app or a baseline model to the mobile device, and generating a user detection model based on a baseline model and at least one behavior model plurality of behavior models updated by dynamic data associated with the mobile device collected while an authorized user employs the mobile device. The method also includes deploying the user detection model to the mobile device if the user detection model was remotely generated, measuring further dynamic data to predict behaviors in the user detection model while a user operates the mobile device, and determining if a user is an authorized user based on how closely measured behaviors match the trained behaviors in the user detection model.



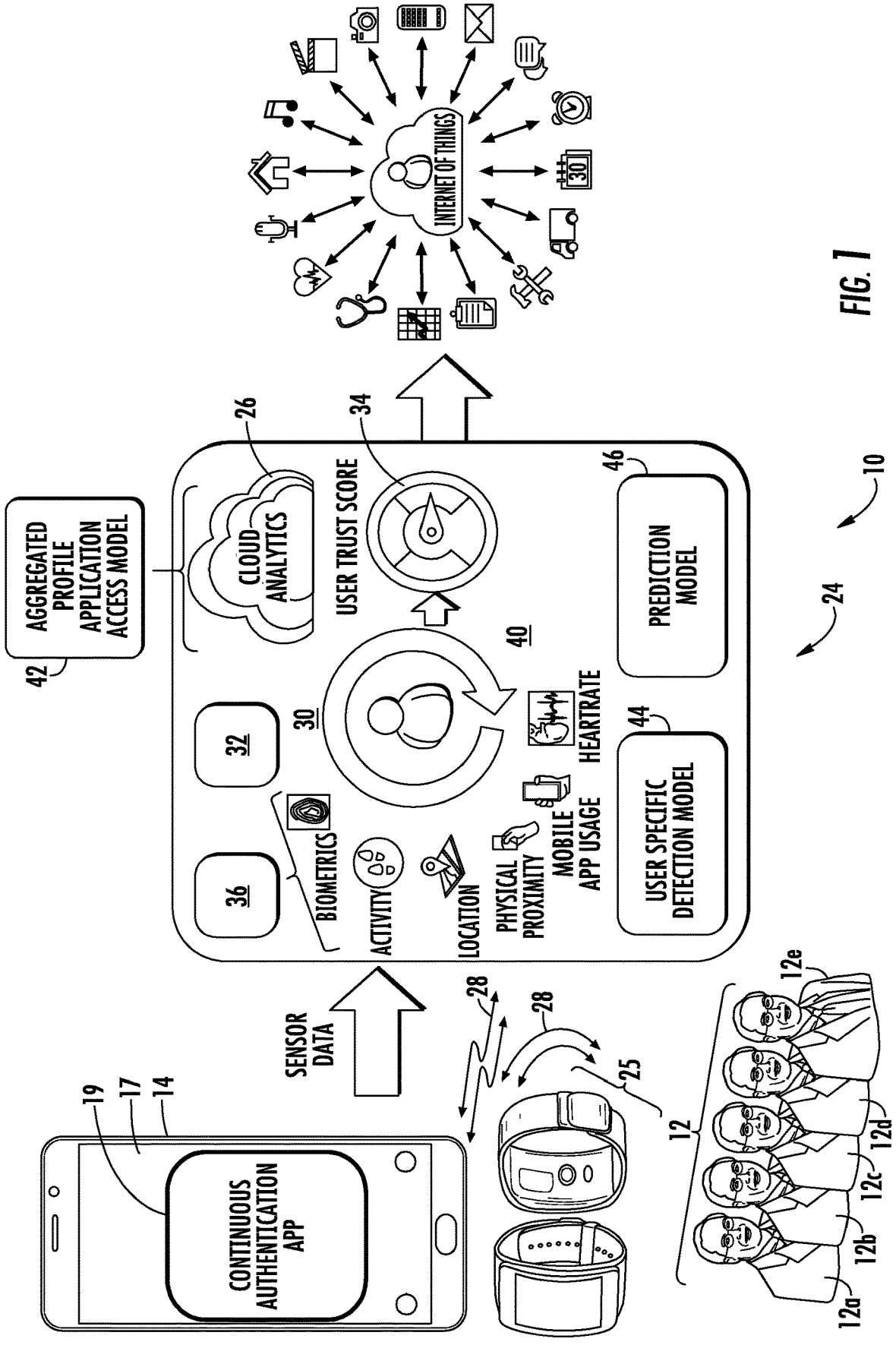

INTERNET OF THINGS
AGGREGATED PROFILE APPLICATION ACCESS MODEL
42
CLOUD ANALYTICS
26
USER TRUST SCORE
34
PREDICTION MODEL
46
10
24
40
30
32
36
BIOMETRICS
ACTIVITY
LOCATION
PHYSICAL PROXIMITY
MOBILE APP USAGE
HEARTRATE
USER SPECIFIC DETECTION MODEL
44
SENSOR DATA
28
28
25
12
12a
12b
12c
12d
12e
19
17
14
CONTINUOUS AUTHENTICATION APP

FIG. 1

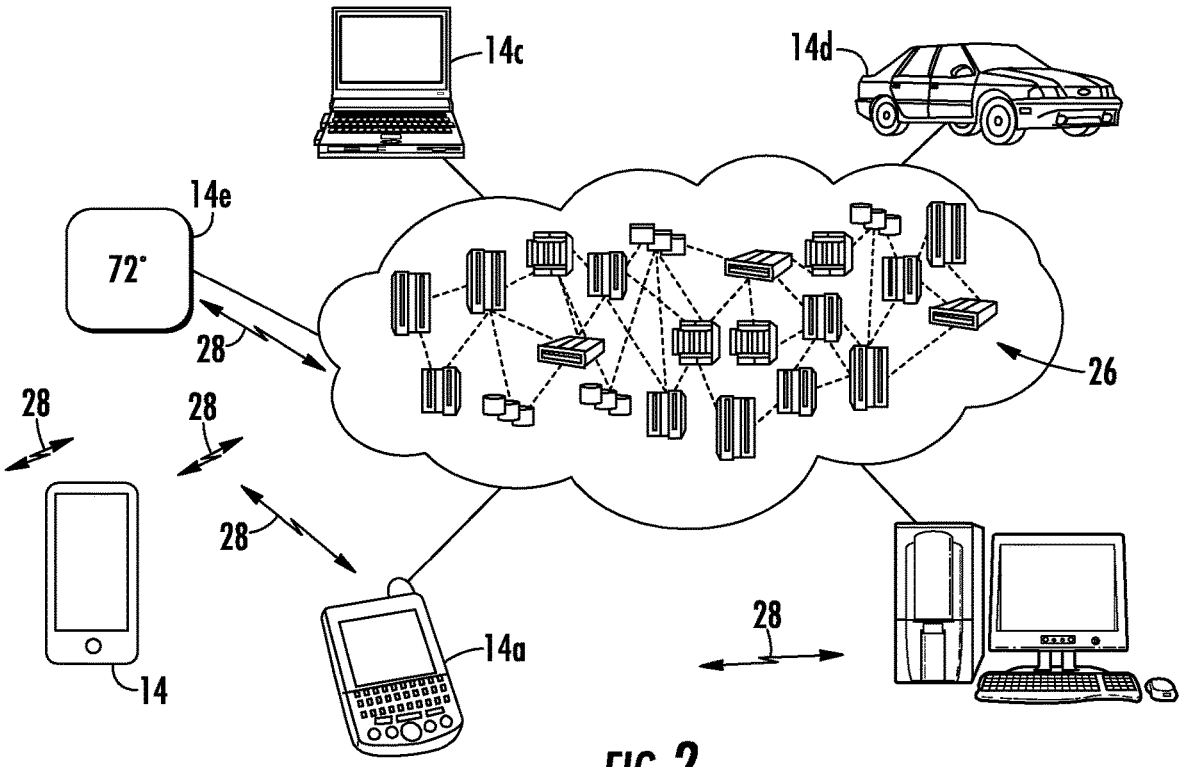


FIG. 2

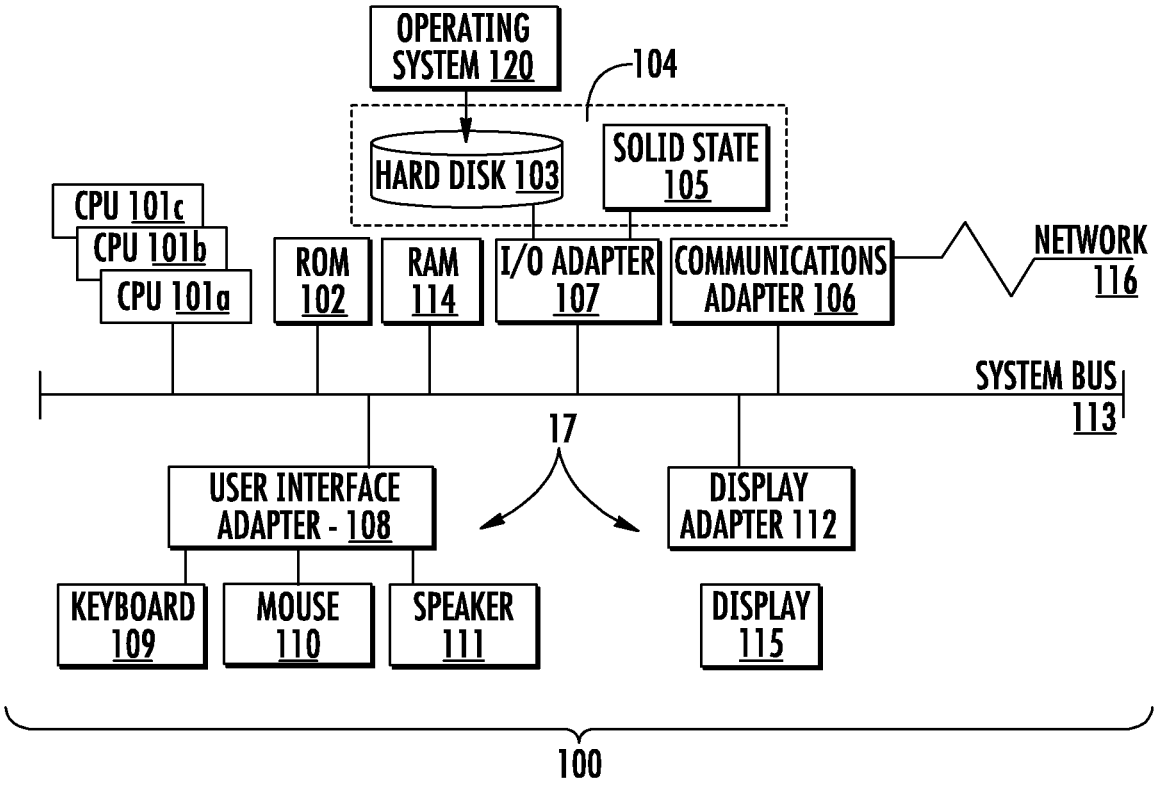

OPERATING SYSTEM 120
104
HARD DISK 103
SOLID STATE 105
CPU 101c
CPU 101b
CPU 101a
ROM 102
RAM 114
I/O ADAPTER 107
COMMUNICATIONS ADAPTER 106
NETWORK 116
SYSTEM BUS 113
17
USER INTERFACE ADAPTER - 108
DISPLAY ADAPTER 112
KEYBOARD 109
MOUSE 110
SPEAKER 111
DISPLAY 115
100

FIG. 3

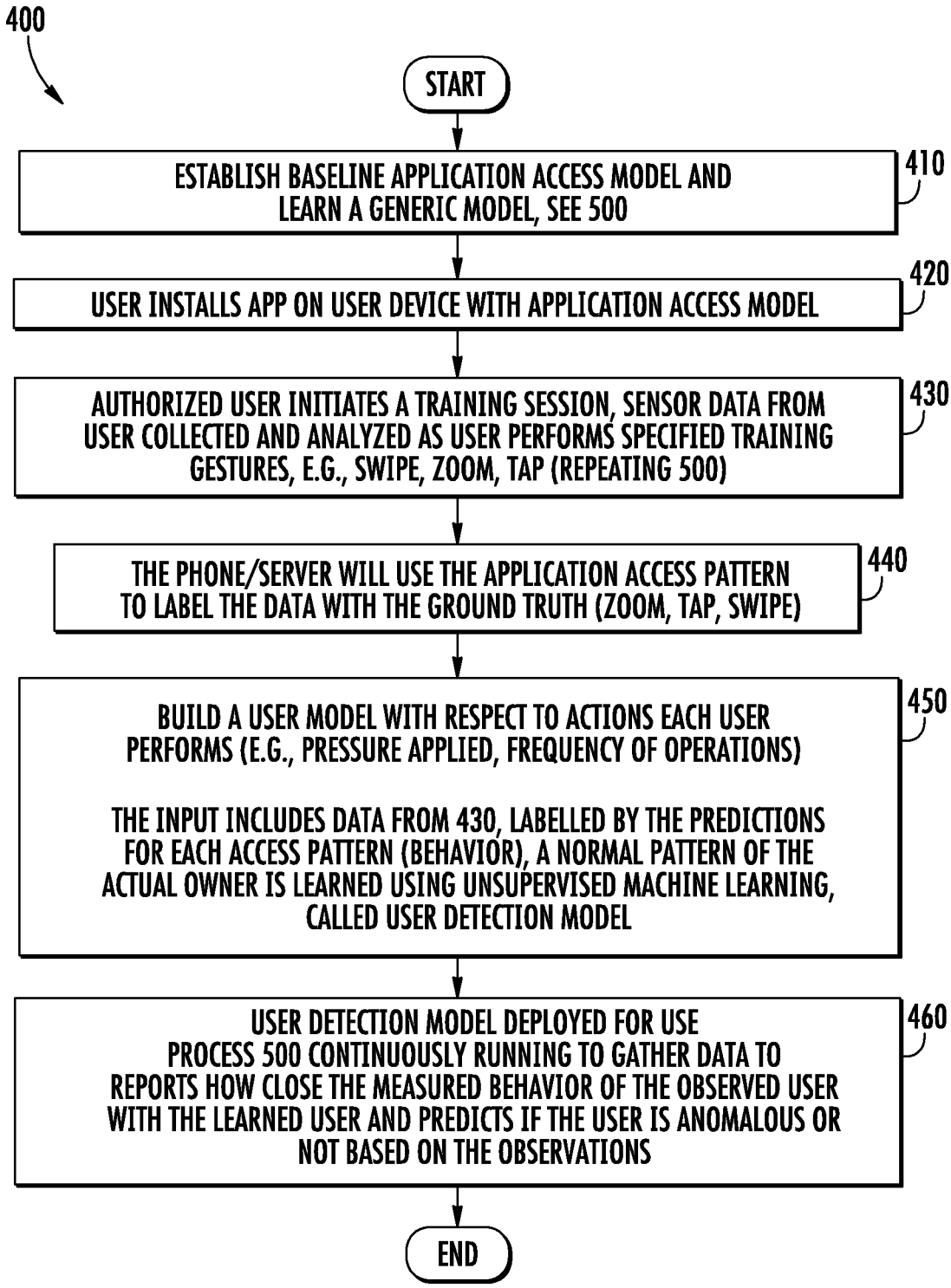

400
START
ESTABLISH BASELINE APPLICATION ACCESS MODEL AND LEARN A GENERIC MODEL, SEE 500
410
USER INSTALLS APP ON USER DEVICE WITH APPLICATION ACCESS MODEL
420
AUTHORIZED USER INITIATES A TRAINING SESSION, SENSOR DATA FROM USER COLLECTED AND ANALYZED AS USER PERFORMS SPECIFIED TRAINING GESTURES, E.G., SWIPE, ZOOM, TAP (REPEATING 500)
430
THE PHONE/SERVER WILL USE THE APPLICATION ACCESS PATTERN TO LABEL THE DATA WITH THE GROUND TRUTH (ZOOM, TAP, SWIPE)
440
BUILD A USER MODEL WITH RESPECT TO ACTIONS EACH USER PERFORMS (E.G., PRESSURE APPLIED, FREQUENCY OF OPERATIONS)
THE INPUT INCLUDES DATA FROM 430, LABELLED BY THE PREDICTIONS FOR EACH ACCESS PATTERN (BEHAVIOR), A NORMAL PATTERN OF THE ACTUAL OWNER IS LEARNED USING UNSUPERVISED MACHINE LEARNING, CALLED USER DETECTION MODEL
450
USER DETECTION MODEL DEPLOYED FOR USE
PROCESS 500 CONTINUOUSLY RUNNING TO GATHER DATA TO REPORTS HOW CLOSE THE MEASURED BEHAVIOR OF THE OBSERVED USER WITH THE LEARNED USER AND PREDICTS IF THE USER IS ANOMALOUS OR NOT BASED ON THE OBSERVATIONS
460
END

FIG. 4

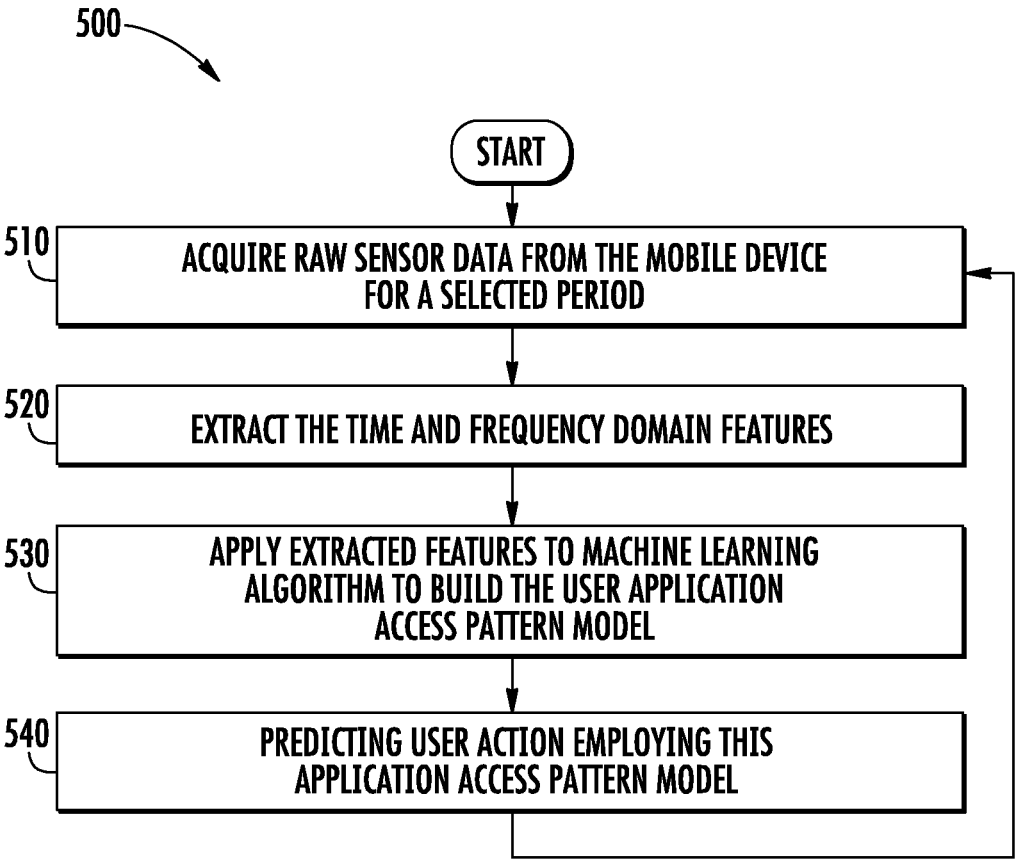

500
START
510
ACQUIRE RAW SENSOR DATA FROM THE MOBILE DEVICE FOR A SELECTED PERIOD
520
EXTRACT THE TIME AND FREQUENCY DOMAIN FEATURES
530
APPLY EXTRACTED FEATURES TO MACHINE LEARNING ALGORITHM TO BUILD THE USER APPLICATION ACCESS PATTERN MODEL
540
PREDICTING USER ACTION EMPLOYING THIS APPLICATION ACCESS PATTERN MODEL

FIG. 5

RECOGNIZING USERS WITH MOBILE APPLICATION ACCESS PATTERNS LEARNED FROM DYNAMIC DATA

FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT

[0001] This invention was made with Government support under contract number D15PC00155 awarded by the United States Department of Homeland Security. The Government has certain rights in the invention.

TECHNICAL FIELD

[0002] Embodiments relate generally to applications for recognition and authentication of users of a mobile device based on application access patterns learned from dynamic data. More particularly, to initial or continuous authentication schemes for a user of a mobile device based on user profiles established based on dynamic data.

DESCRIPTION OF RELATED ART

[0003] Personal electronic devices or mobile phones and there applications are prolific and widespread. Such electronic devices can provide a user with wireless phone access, Internet access, the ability to perform online transactions (e.g., on-line shopping, on-line banking, etc.) as well as other applications such as finding maps to particular locations, among many other things. Widespread use and application of electronic devices that are available today increase user productivity and quality of life.

[0004] In the many industries, enhancing customer satisfaction is a priority. Faced with increased industry competition, many operators and retailers are looking for smarter ways to maximize customer satisfaction, improve customer services, and generate more revenue. Expanding how customers access available facilities and services has proven to be a successful strategy. By way of a non-limiting example, electronic devices such as televisions, controllers user computers, user mobile devices, tablets, and the like play an important role in providing interfaces, authentication, and implementing services. Likewise such devices facilitate providing access to and authentication or verification of user identity in advance of providing access to a facility or providing such services. Users are increasingly using a variety of apps on their personal mobile devices facilitate to access to building spaces, define preferences, investigate, request, pay for and receive services. However, such services may require a different app for each service requested which can become cumbersome and burdensome.

[0005] Unfortunately, electronic devices (and especially mobile devices) are also susceptible to loss, theft, or unauthorized use. Electronic devices often carry private, confidential, and/or difficult-to-replace data, and the loss of such data further compounds the loss of the electronic device. Additionally, the authorized user of a lost or stolen electronic device may have to deal with ramifications such as the misuse of information or someone else gaining access to information stored on the mobile device. Furthermore, electronic devices are often used to run diverse applications that originate from many sources, which can sometimes lead to users unknowingly installing applications with malicious intent (e.g., malware) onto electronic devices. Such malware may impersonate the authorized user, send unauthorized messages (e.g., to conduct transmissions that debit the telecommunication account associated with the electronic device, usually in an attempt to generate revenue for the attacker), steal personal data, or engage in other malicious and/or unauthorized activity.

[0006] Previous attempts have been made to prevent unauthorized use or otherwise stop attacks against electronic devices. For example, some electronic devices are equipped with locking features that require a code or personal identification number (PIN) to unlock the electronic device. Unfortunately, many users do not utilize such authorization schemes such that locking features tend to be ineffective, and moreover, thieves can easily overcome such authorization schemes because unlock codes tend to be short and predictable so as to be memorable to users. Some more sophisticated user authentication solutions may be cumbersome, or inadequate for users to fully realize the benefits of the mobile devices. For example, some result in degraded user experiences (requiring users to authenticate multiple times when the device is used), lack of user-specific service access rights, poor security practices, insufficient security, lack of continuous authentication and poor performance of biometric solutions. Moreover, many existing techniques also have limitations. For example, gait based techniques cannot identify the owner of the device, if the user is not performing any activity, while solutions using touch dynamics, keystroke dynamics require modifications to existing app to understand user touch and keystroke patterns.

[0007] Accordingly, with the ubiquity of electronic devices and the ever-present threat that electronic devices may potentially be stolen or subject to unauthorized use, improved techniques to improve user identification/authentication, detect electronic device theft, and/or unauthorized usage are desired. As such, it would be advantageous to resolve these challenges with means of leveraging the processing and sensing capabilities of mobile and wearable devices to create user-specific unique signatures based on behavioral traits that can enable usable security.

BRIEF SUMMARY

[0008] Described herein in an embodiment is a method of continuous user authentication on a mobile device including: establishing a baseline model generated based on acquiring dynamic data associated with the mobile device, deploying at least one of a training app or a baseline model to the mobile device, and generating a user detection model based on a baseline model and at least one behavior model plurality of behavior models updated by dynamic data associated with the mobile device collected while an authorized user employs the mobile device. The method also includes deploying the user detection model to the mobile device if the user detection model was remotely generated, measuring further dynamic data to predict behaviors in the user detection model while a user operates the mobile device, and determining if a user is an authorized user based on how closely measured behaviors match the trained behaviors in the user detection model.

[0009] In addition to one or more of the features described above, or as an alternative, further embodiments may include that at least one behavior model of a plurality of behavior models includes user gestures associated with using the mobile device.

[0010] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the plurality of user gestures associated with

using the mobile device includes at least one of a tap to select, a swipe, a scroll, and a pinch.

[0011] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the behavior model of a plurality of behavior models includes: at least one of unlocking the mobile device, entering data into the device, answering a call on the mobile device, patterns with respect to the keystrokes that a certain operator makes to enter input into the device, and biometrics.

[0012] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the biometrics include at least one of heart rate, respiration rate, and skin conductivity.

[0013] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the baseline application access model is updated on a plurality of baseline application models from other users.

[0014] In addition to one or more of the features described above, or as an alternative, further embodiments may include acquiring dynamic data associated with the mobile device further includes: acquiring raw dynamic sensor data from the mobile device for a selected duration; extracting time and frequency domain features in the raw dynamic sensor data; and building at least one behavior model of a plurality of behavior models by applying extracted time and frequency domain features to a learning algorithm.

[0015] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the dynamic data includes at least one of rotational accelerations, rotational rates, rotation, translational accelerations, translational velocities, and position data, associated with the mobile device.

[0016] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the position data is based on at least one of accelerometer, gyroscope and GPS data.

[0017] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the baseline application access model is an aggregate of a plurality the baseline application access models associated with a plurality of user devices.

[0018] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the baseline application access model, is aggregated on a remote server based on a plurality the baseline application access models associated with a plurality of user devices.

[0019] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the user detection model, is an aggregate of a plurality user detection models.

[0020] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the user detection model, is aggregated on a remote server.

[0021] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the at least one behavior model is independent of user application touch sensor data.

[0022] In addition to one or more of the features described above, or as an alternative, further embodiments may include establishing a trust score associated with the determining, the trust score providing a weighting of how closely the measured behaviors match the trained behaviors in the user detection model.

[0023] In addition to one or more of the features described above, or as an alternative, further embodiments may include that a trust score greater than a selected threshold indicates a sufficient match for authentication.

[0024] In addition to one or more of the features described above, or as an alternative, further embodiments may include taking security precautions with the user device if the user is identified as not an authorized user.

[0025] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the security precautions include at least one of sounding an alarm, locking the mobile device, placing a call to law enforcement, shutting the mobile device off.

[0026] In addition to one or more of the features described above, or as an alternative, further embodiments may include acquiring data from a wearable device and establishing at least one behavior model of the plurality of behavior models generated based on the data associated with the wearable device.

[0027] In addition to one or more of the features described above, or as an alternative, further embodiments may include that the data associated with the wearable device is biometric data associated with the user.

[0028] Also described herein in an embodiment is a system for continuous user authentication on a mobile device. The system includes a user device, a server operably connected to the user device, and at least one of the server and the user device configured to execute a method of continuous user authentication on the mobile device. The method includes establishing a baseline application access model, the baseline application access model based on at least one behavior model of a plurality of behavior models generated based on acquiring dynamic data associated with the mobile device, deploying at least one of a training app or a baseline application model to the mobile device, and generating user detection model, the user detection model based on at least one baseline application access model and at least one behavior model of the plurality of behavior models updated by dynamic data associated with the mobile device collected while an authorized user employs the mobile device to access an application. The method also includes deploying the user detection model to the mobile device if the user detection model was remotely generated, measuring further dynamic data to predict behaviors in the user detection model while a user operates the mobile device, and determining if a user is an authorized user based on how closely measured behaviors match the trained behaviors in the user detection model.

[0029] Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein. For a better understanding of the disclosure with the advantages and the features, refer to the description and to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The subject matter which is regarded of the described embodiments is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the described embodiments are apparent from the

following detailed description taken in conjunction with the accompanying drawings in which:

[0031] FIG. **1** depicts a simplified diagrammatic view of the system and interfaces for implementing the methodology of continuous user authentication in accordance with an embodiment;

[0032] FIG. **2** is a depiction of a cloud computing environment as may be employed in accordance with an embodiment;

[0033] FIG. **3** depicts a simplified block diagram of a computing system as may be implemented in a user device in accordance with an embodiment;

[0034] FIG. **4** depicts a flowchart of an example method of continuous user authentication in accordance with an embodiment; and

[0035] FIG. **5** depicts a flowchart of an example method of acquiring data for continuous user authentication in accordance with an embodiment.

DETAILED DESCRIPTION

[0036] For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of this disclosure is thereby intended. The following description is merely illustrative in nature and is not intended to limit the present disclosure, its application or uses. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features. As used herein, the term controller refers to processing circuitry that may include an application specific integrated circuit (ASIC), an electronic circuit, an electronic processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, and/or other suitable interfaces and components that provide the described functionality.

[0037] Additionally, the term "exemplary" is used herein to mean "serving as an example, instance or illustration." Any embodiment or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or designs. The terms "at least one" and "one or more" are understood to include any integer number greater than or equal to one, i.e. one, two, three, four, etc. The terms "a plurality" are understood to include any integer number greater than or equal to two, i.e. two, three, four, five, etc. The term "connection" can include an indirect "connection" and a direct "connection".

[0038] Embodiments related to a method for authenticating a user with a mobile device based on the way user accesses, interfaces, and utilizes various mobile applications. Advantageously the described method enables continual, strong and user-friendly context-aware authentication for data protection and service usage control. The method is based on integrating existing service access technologies with mobile device sensors and perception systems using our novel techniques for multi-sensor fusion, multivariate time series classification and segmentation algorithms, risk-based dynamic access control inference engine and context-aware remote management. Uniquely, rather than employing data associated with the individual applications a profile for the user is built from dynamic data, e.g., accelerometer and gyroscope data, as the user employs various applications on the mobile device. In the described embodiments, two techniques are employed. First, the raw dynamic data e.g., accelerometer and gyroscope data is collected from the mobile device to understand if the user is scrolling, tapping or zooming the app (referred to application access pattern), and the like. Second, a learning algorithm is employed to learn (teach) an individual model per user application access pattern. This model is then used to predict a trustworthiness score of user while accessing the applications. Advantageously, such an approach does not rely on receiving and understanding data from individual applications and therefore avoids privacy concerns as no access to particular user data or data in apps is required. In other words, the approach employed in the described embodiments does not user or receive any actual data from the application that employed by the user. As such, no actual data associated with the application the user is employing is passed from the user app to authentication methodology or application. This is very privacy aware solution as it only observes raw sensor data and not any text or logs in the mobile device.

[0039] Advantageously, the described embodiments provide a passive technique that will recognize a user and provide user authentication continuously and essentially real time based on dynamic data associated with the way applications on a control device or mobile device are accessed. Moreover the described embodiments facilitate preventing aggressive malicious mobile app/user from accessing sensitive resources and facilitate the identification and distinguishing of individual users to permit customization of services based on identity Such an approach in an embodiment can identify how to learn the to identify and authenticate users based on the raw accelerometer and gyroscope data collected. Fortunately, these datasets can be easily collected without requiring modification to the system protect from lost or stolen devices.

[0040] Referring now to the drawings, FIG. **1** illustrates a diagrammatic overview of a system **10** for recognition and authentication of users **12** based on access patterns. In particular, access patterns learned from dynamic data measured while a user **12** uses a user device **14** or accesses one or more applications, or even a learning application on a user device **14**. Dynamic data includes position, rotation and acceleration measured by dynamic sensor(s) in the user device **14**. The dynamic data may include three-axis translational and rotational accelerations, three-axis translational and rotational velocities, three axis rotation angles, and instantaneous positions, and geographic positions. The system **10** may include a controller or server denoted generally as **24** that is employed to interface with a user device **14** and execute processes for recognition and authentication in accordance with the embodiments described herein. In addition, some, or all of the functionality provided may be based on methods and processes executed locally or remotely such as on a local or remote server **24** and/or cloud computing environment **26**. As will be appreciated the cloud computing environment **26** could include a local or remote server **24**, or the server **24** and cloud computing environment **26** could be entirely remote. The system **10** may also include a local and remote communication network and system, shown generally as **28** for facilitating communication and control of various features in the system **10** as well as for facilitating communication between a user device **14**, server **24**, and the cloud computing environment **26**, other components and sensors in the system and the like. Likewise, the system **10** may also include one or more application(s) (app) **19**

operable on the user device **14**, that permits and facilitates the user **12** to enter and receive information and for user device **14** to communicate with, interface with, and control selected aspects of system **10**. The app **19** and the user device **14** may include a user interface **17** to enable the user **12** to interface with the user device **14** and the app **19** being executed thereon. In an embodiment, the app **19** may be employed by the user **12**, for example to facilitate user authentication and access permissions to the building system. The app **19** may also facilitate establishing user preferences associated with the system **10** and methods described herein.

[0041] Server **24** may be part of a cloud computing environment **26**. Cloud computing is a widely adopted and evolving concept. Generally, cloud computing refers to a model for enabling ubiquitous, convenient, and on-demand access via Internet to shared pools of configurable computing resources such as networks, servers, storages, applications, functionalities, and the like. There are a number of benefits associated with cloud computing for both the providers of the computing resources and their customers. For example, customers may develop and deploy various business applications on a cloud infrastructure supplied by a cloud provider without the cost and complexity to procure and manage the hardware and software necessary to execute the applications. The customers do not need to manage or control the underlying cloud infrastructure, e.g., including network, servers, operating systems, storage, etc., but still have control over the deployed applications. On the other hand, the provider's computing resources are available to provide multiple customers with different physical and virtual resources dynamically assigned and reassigned according to clients' load. Further, cloud resources and applications are accessible via the Internet.

[0042] Referring now to FIG. **2**, an illustrative cloud computing environment **26** is depicted. As shown, cloud computing environment **26** includes one or more cloud computing nodes, such as processing or communication nodes e.g., servers **24** (FIG. **1**) with which, user devices (generally referred to as **14**), computing devices and controllers all denoted in various configurations as **14***a-e* may communicate. Cloud computing nodes **24** may communicate with one another and/or be grouped (not shown) physically or virtually, in one or more networks, such as Private, Community, Public, or Hybrid clouds, or in one or more combinations thereof. This allows cloud computing environment **26** to offer infrastructure, platforms and/or software as services for which a cloud consumer does not need to maintain or minimize resources at a local computing device level. It is understood that the types of user/computing devices **14** shown in FIG. **2** are intended to be illustrative only and that computing nodes and cloud computing environment **26** can communicate with any type of computerized device over any type of network and/or network addressable connection (e.g., using a web browser).

[0043] The computing devices **14***a-e* such as user device **14** may be any form of a mobile device (e.g., smart phone, smart watch, wearable technology, laptop, tablet, etc.). The user device **14** can include several types of devices, in one instance, even a fixed device, e.g. a keypad/touch screen affixed to a wall in a building corridor/lobby, such as building system controllers. In other words, the server **24** and the user device **14** can all be computing devices **14***a-e*. It should be appreciated that the servers **24** are typically part of the installed building system infrastructure, while the user device **14** is typically owned and used by the user **12**, service man, homeowner, and the like. The term "user device" **14** is used to denote all of these types of devices as may be employed by the user **12**. For example, in an embodiment, the computing devices **14** could be, a personal digital assistant (PDA) or cellular telephone tablet **14***a*, such as user device **14**, desktop computer/terminal/server **14***b*, laptop computer **14***c*, a vehicle **14***d*, or a control panel of some sort for a building system **14***e*, and the like. User devices **14***a-e* may also be configured to communicate with each other or a variety of sensors directly or via communication network **28**.

[0044] The computing devices, **14***a-e* such as user device **14**, as well as other components of the system **10** can communicate with one another, in accordance with the embodiments of the present disclosure, e.g., as shown in FIG. **1**. For example, one or more user devices **14** or a server **24** may communicate with one another when proximate to one another (e.g., within a threshold distance). The user device **14** and server **24** may communicate over one or more communication networks **28**, (e.g., a communication bus) that may be wired or wireless. Wireless communication networks can include, but are not limited to, Wi-Fi, short-range radio (e.g., Bluetooth®), near-field (NFC), infrared, cellular network, etc. In some embodiments, user device **14** (e.g., the computing devices **14***a*-**14***e* may include, or be associated with (e.g., communicatively coupled to) one or more other networked building elements (not shown), such as computers, beacons, other system controllers, bridges, routers, network nodes, etc. The networked elements may also communicate directly or indirectly with the user devices **14** using one or more communication protocols or standards (e.g., through the network **28**). For example, the networked element may communicate with the user device **14** using near-field communications (NFC) and thus enable communication between the user device **14** and any other components in the system **10** when in close proximity to the user device **14** (NFC is a short range wireless protocol). Or, for example, the networked element may communicate with the user device **14** using Bluetooth and thus communicate a unique ID and enable communication between the user device **14** and any other components in the system **10** from a further distance. The network **28** may be any type of known communication network including, but not limited to, a wide area network (WAN), a local area network (LAN), a global network (e.g. Internet), a virtual private network (VPN), a cloud network, and an intranet. The network **28** may be implemented using a wireless network or any kind of physical network implementation known in the art. The user devices and/or the computing devices **14** may be coupled to the server **24**, through multiple networks (e.g., cellular and Internet) so that not all user devices and/or the computing devices **14** are coupled to the any given server **24** or component through the same network **28**. One or more of the user devices **14** and servers **24** may be connected in a wireless fashion. In one non-limiting embodiment, the network **28** is the Internet and one or more of the user devices **14** executes a user interface application (e.g. a web browser, mobile app) to contact and communicate through the network **28**.

[0045] Referring to FIG. **3**, the computing devices **14***a-e*, including user device **14**, may include a processing/computing system **100** including a processor, memory, and com-

munication module(s), as needed to perform the functions of recognition and authentication based on dynamic data in accordance with an embodiment. In one embodiment, the computing devices **14***a-e*, including user device **14** and servers **24** each may include a computing system **100** having a computer program stored on nonvolatile memory to execute instructions via a microprocessor related to aspects of recognition and authentication based on dynamic data in accordance with the embodiments described herein.

[0046] In an embodiment, the computing system **100** has one or more processing units (processors) **101***a*, **101***b*, **101***c*, etc. (collectively or generically referred to as processor(s) **101**). The processor **101** can be any type or combination of computer processors, such as a microprocessor, microcontroller, digital signal processor, application specific integrated circuit, programmable logic device, and/or field programmable gate array. As is conventionally done, the processors **101** are coupled to system memory and various other components via a system bus **113**. The memory can be a non-transitory computer readable storage medium tangibly embodied in the user device **14** or server **26** including executable instructions stored therein, for instance, as firmware or mass storage **104**. Read only memory (ROM) **102** is coupled to the system bus **113** and may include a basic operating system, which controls certain basic functions of system **100**. Random Access Memory (RAM) **114** is also coupled to the system bus **113** and may include a basic storage space to facilitate program execution.

[0047] FIG. **3** further depicts an input/output (I/O) adapter **107** and a network or communications adapter **106** coupled to the system bus **113**. I/O adapter **107** communicates with hard disk **103** and/or solid state storage **105** or any other similar component. I/O adapter **107**, hard disk **103**, and solid state storage **105** are collectively referred to herein as mass storage **104**. As is conventionally done an operating system **120** for execution on the computing system **100** may be stored in mass storage **104**. A communications adapter **106** interconnects bus **113** with an outside network **116** such as and including communications network **28** and the like, enabling computing system **100** to communicate with other such systems. The communications adapter **106** may implement one or more communication protocols as described in further detail herein, and may include features to enable wired or wireless communication with external and/or remote devices separate from the user device **14**. The computing device **14***a-e* including the user device **14** and/or server **24** may further include a user interface, shown generally as **17**, e.g., a display screen, a microphone, speakers, input elements such as a keyboard **109** or touch screen, etc. as shown in FIG. **3**) as is known in the art. A screen (e.g., a display monitor) **115** is connected to system bus **113** by display adaptor **112**, which may include a graphics adapter and a video controller. A keyboard **109**, mouse **110**, and speaker **111** all interconnected to bus **113** via user interface adapter **108**. It should be appreciated that in some embodiments some or all of these elements of the computing system **100** may be integrated. In one embodiment, adapters **107**, **106**, and **112** may be connected to one or more I/O busses that are connected to system bus **113** via an intermediate bus bridge (not shown). Suitable I/O buses for connecting peripheral devices may also be employed. Additional input/output devices are shown as connected to system bus **113** via user interface adapter **108** and display adapter **112**. It should be appreciate that the components of the computing system as described are for illustration purposes only. Features and functions as described may be omitted, integrated, or distributed as desired and as required to suit a particular application.

[0048] Referring once again to FIG. **1**, in an embodiment, various behaviors, activities, or attributes **32** of a user **12** are monitored. For example, behaviors activities, or attributes **32** (hereinafter behaviors) of a user **12** may include, but not be limited to, biometrics, user activities, location, app usage, user proximity to the user device **14**, and user characteristics such as heart rate, respiration and the like. The behaviors **32** are monitored on a user device **14** to generate a profile model **30** associated with an authorized user, e.g., **12***a*. The behavior models **32** are the employed with a trust score **34** associated with selected actions described in further detail herein may be used to generate the profile model **30** and determine whether a current operator/user **12***a*-**12***e* using the electronic device **14** is the authorized user **12***a*. The objective is to distinguish between an authorized user **12***a* or some other user **12***b* (e.g., a potential thief who physically stole the electronic device and is now using the device **14**, a malicious user **12***c* who has obtained unlock or other authentication credentials and is improperly using the user device **14**, an authorized secondary user **12***d* such as the authorized user's **12***a* spouse or child **12***e*, etc.). More particularly, whereas current approaches to detecting unauthorized usage of a user device **14** tend to measure one or more particular attributes (e.g., a time from device pick-up as sensed with an accelerometer to the time that the user **12** first touches the device **14**) and then establish a threshold with respect to the measured attributes to characterize the user **12**, which can result in thresholds that are either excessively sensitive or excessively lax.

[0049] In various embodiments, the electronic device **14** may comprise an observation function or process **36** configured to capture one or more behavior features **32** that represent salient behaviors **32** observed on the electronic device **14** based on dynamic data captured while the user **12** is exhibiting such behaviors. Furthermore, additional example behaviors **32** that the observation function **36** may observe may comprise information based on an events and notifications (e.g., push notifications received at the user device **14**), actions that may include, without limitation, unlocking the user device **14**, entering data into the user device **14**, answering a call, etc., keystroke-based identity profiles (e.g., positions, timings, and patterns with respect to the keystrokes that a certain operator makes to enter input into the user device **14**), application installation and usage frequencies, and so on. Other behaviors **32** observed may be related to biometrics for the user **12**. For example, as a user **12** accesses the user device **14**, biometric information associated with that particular user **12** may be collected and recorded. Such biometric data may include, but not be limited to heart rate, respiration, skin conductivity, respiration, and the like. Accordingly, those skilled in the art will appreciate that the observation function **36** may broadly capture the behaviors **32** to represent any suitable behaviors **32** that can be observed on the electronic device **14** and attributed to a user **12** and more particularly, a certain user **12***a*, **12***b*, and the like. In various embodiments, the behaviors **32** observed and generated at the observation process **36** may then be analyzed by executing one or more machine

learning algorithms **40** to cluster the behavior **32** and thereby construct a behavior models **30** related to the observed behaviors **32**.

[0050] Accordingly, in various embodiments, the observation function may be configured to monitor or otherwise collect local behavioral information on the electronic device **14** through one or more application program interface (API) calls and minimal instrumentation at one or multiple levels in an operating system stack, whereby the observation function may utilize fast and efficient in-memory processing to monitor, measure, or otherwise observe behavioral information associated with the electronic device **14** and generate one or more behaviors models **34** that describe the observed behaviors **32** in concise or consolidated terms.

[0051] Turning now to FIG. **4** as well, in an embodiment the processes of continuous authentication of the described embodiments are functionally segregated into three processes. First a development of a baseline application access model based on a variety of collective behavior models associated with a user's actions on a user device **14**. Second, development of a user detection model based on initial training of application access model with a known authorized user e.g., **12***a*. Finally prediction and determination of an authorized or unauthorized user **12** by collecting data and evaluating the data in the user detection models **44** to identify how closely the current user's measured behaviors **32** match those established during the training. A close match of behaviors **32** is indicative of identifying an authorized user e.g., **12***a*.

[0052] For example, in an embodiment the observation function **36** may be employed in multiple phases of a process for continuous authentication as described herein. In a first phase during an initialization or "training" phase, the observation function **36** may monitor behaviors **32** on the device **14** over a predefined time period comprising (e.g., several) minutes, hours days, wherein the behaviors **32** observed over the time period may be mapped and recorded. As such, the observation function **36** may extract the behavior models **30** that represent the observed behaviors over the time period, wherein the extracted behavior models **30** each represents a behavior **32** type (e.g., notifications, location updates, etc.) and each entry in the behavior models **30** represents one observed behavior **32** having the respective type.

[0053] In various embodiments, the electronic device **14** may then store the local profile application access model **30** in a local model repository on the electronic device **14**. In addition, the electronic device **14** may upload the local profile application access model **30** to a server **24** e.g., cloud computing environment **26**, which may further receive profile application access models **30** uploaded from various other devices **14**. The server **24** or cloud computing environment **26** may then execute algorithms on the local profile application access model(s) **30** uploaded from the electronic device **14** in combination with the profile application access models **30** uploaded from the various other devices **14** to create an aggregate baseline profile application access models **42** (FIG. **1**). This baseline profile application access model **42** provides a baseline generic model for all the behaviors **32**. Furthermore, the server/cloud computing environment **26** may compare the local profile application access model **30** uploaded from the electronic device **14** (and the profile application access models **30** uploaded from the various other devices **14**) to the baseline profile application access models **42** to determine the baseline profile model **30** closest to each respective profile model **30** that was uploaded to and clustered on the server/cloud computing environment **26** to form the baseline profile models **42**. For example, in various embodiments, the server/cloud computing environment **26** may compare the local profile application access models **30** uploaded thereto with each baseline profile application access model **42** to calculate one or more distance metrics that quantify a semantic and/or syntactic similarity between the local profile models **30** and each respective baseline profile application access model **42**. Accordingly, the server/cloud computing environment **26** may register each local profile application access model **30** as a member within the particular baseline profile application access model **42** closest to the respective local profile application access model **30**, as determined according to the distance metrics (e.g., distance metrics based on aggregate or global rule comparisons that can quantify similarities in syntactic form and individual or content-based rule comparisons that can quantify similarities in semantic meaning). Accordingly, depending on the particular distance metric(s) used, the server/cloud computing environment **26** may identify one baseline profile application access model **42** closest to each respective local profile application access model **30** such that each local profile model **30** may be a member in the closest baseline profile application access model **42**. Furthermore, in various embodiments, the server/cloud computing environment **26** may track the membership in the baseline profile application access models **42** over time to create and maintain anonymous user behavior profiles (not shown).

[0054] In various embodiments, the electronic device **14** (and other user devices **14** associated with other profile application access models **30**) may then download the baseline profile application access models **42** from the server/cloud computing environment **26** and store the downloaded baseline profile application access models **42** together with the initial local profile application access model **30** on a specific user device **14**. Furthermore, the user device **14** may store information to indicate the current baseline profile application access model **42** in which the local profile application access model **30** was assigned membership. As such, the initial local profile application access model **30** generated on the device **14**, the baseline profile application access models **42** downloaded from the server/cloud computing environment **26**, and the information stored indicating the current membership associated with the local profile application access model **30** can be used to authenticate a current user **12** or operator associated with the electronic device **14** and thereby detect potential theft, unauthorized usage, authorized operator changes, etc.

[0055] More particularly, in an embodiment, the observation function **36** may continue to monitor user behavior(s) **32** on the electronic device **14** in a substantially continuous and similar manner to that described above. However, whereas the observation function **36** monitored the user behavior **32** over an "extended" selected period during the initialization or "training" phase used to create the initial local profile application access model **30** and the baseline profile application access models **42**, in this instance the observation function **36** may monitor the user behavior(s) **32** on the device **14** over smaller time periods (e.g., on the order of a few minutes) during subsequent phases that are directed to particular user authentication, identity verification, theft

detection, operator change detection, etc. Accordingly, as described above, the process may be continuously performed as described above to refine the local profile application access model **30**.

Prediction Models

[0056] In various embodiments, a comparison may then be conducted to compare the new local profile models **30** that are rebuilt as described above to each baseline profile model **42** downloaded from the server/cloud computing environment **26**. For example, in various embodiments, a new local profile model **30** may be compared to a downloaded baseline profile models **42** according to the various distance metrics described in further detail above. As such, once again the comparison facilitates determining a net/normalized distance from the local profile model **30** to each baseline profile model **42** to quantify syntactic and/or semantic similarities therebetween and identify the baseline profile model **42** closest to the local profile model **30** accordingly. Moreover, in various embodiments, the comparison may then generate an identity authentication of a user **12***a*-**12***e* (or operator) associated with the electronic device **14** as the prior user e.g., **12***a*, **12***c*, **12***e*, who engaged in the behavior **32** during the training phase that resulted in the initial local profile model **30**. For example, if the current user or operator **12** is the prior (authorized) user **12***a*, **12***c*, **12***e*, the new profile model **30** from the most recent observation period should still be closest to the baseline profile model **42** that includes the initial local profile model **30** as a member. Accordingly, in response to determining that the (current) new profile model **30** is closest to the baseline profile model **42** that includes the initial local profile model **30** as a member, the identity authentication generated may authenticate the current user **12** identity with a first level of confidence or outlier score (denoted X), which may be expressed according to a percentage depending on the distance from the current profile model **30** and the baseline profile model **42** closest to the original local profile model **30**. For example, in various embodiments, the confidence measure or outlier scoreX may be inversely proportional to a difference between the distance between the current profile model **30** and the closest baseline profile model **42** and the distance between the original profile model **30** and the closest baseline profile model **42** (e.g., because the distance metrics range from zero to one, where a zero value indicates the least possible distance and a one value indicates the highest possible distance) Further details regarding the outlier score and determining the trust score for discerning anomalous behaviors is addressed at a later point herein.

[0057] However, in response to determining that the current profile model **30** is closest to a different baseline profile model **42** than the original local profile model **30**, the identity authentication may indicate a change in user/operator **12** from the original local profile model **30** to an unauthorized user e.g., **12***b*, **12***d*, which may cause one or more security based actions to occur on the electronic device **14**. For example, possible actions may include having the comparing the current local profile model **30** to local profile models **30** that are associated with one or more authorized users **12***a*, **12***c*, **12***e* (e.g., a spouse or child associated with the primary user **12***a*), which assumes that sufficient "training" behavior was observed with respect to the other authorized users **12***a*, **12***c*, **12***e* to create local profile models **30** associated therewith. Accordingly, in response to the comparison determining that the current local profile model **30** in fact, matches the local profile model **30** associated with another authorized user e.g., **12***c*, the identity authentication may comprise an operator change notification to that effect. Alternatively, where the current local profile model **30** does not match the local profile models **30** associated with any authorized users **12** to a sufficient confidence level (or where there are no authorized secondary users e.g., **12***b*, **12***d* that engaged in sufficient training), the identity authentication process may generate a message communicated internally within the electronic device **14** and/or to the external server/cloud computing environment **26** to disable the user device **14** and initiate recovery and/or protective actions. For example, the identity authentication may cause an internal transmitter on the device **14** to broadcast a current or most recent position fix to thereby assist in finding or otherwise recovering the electronic device **14**. In another example, the identity authentication may start an internal procedure to protect data stored on the device **14** and shut the device **14** down to prevent the unauthorized operator **12** from continuing to use the electronic device **14**. In another example, the user device **14** may automatically take and store pictures for further investigation.

[0058] Accordingly, because the described embodiments support procedures to authenticate a current user or operator **12** associated with the electronic device **14** using profile models **30**, **42** that are based on behaviors **32** observed over time, including behaviors **32** associated with other users **12** that provide an external perspective on the local user profile model **30**, the model generation and comparison techniques described herein can enable more robust and realistic identity thresholds that may be possible through raw comparisons between discrete individual features.

[0059] Turning now to FIG. **4**, for a description of the methodology of in accordance with an embodiment. FIG. **4** is a flowchart depicting high level example of a method **400** for recognizing users **12** with mobile application access patterns based on dynamic data of a user device **14** in accordance with an embodiment. In an embodiment, the method **400** initializes at process step **410** with establishing the baseline application access pattern model **30** as described above to establish the aggregate application access model **42**. In operation, this model may be employed for the baseline for specific user training. That is, the model **30** is continually updated as an authorized user e.g., **12***a*, **12***c*, **12***e*, continues to teach the model **30**.

[0060] Turning now to FIG. **5** as well, depicting a flow chart of the steps for acquiring the dynamic data and building the baseline application access model **30** as depicted by process **510**. In an embodiment, the process **510** initiates with a acquiring the raw dynamic sensor data from the mobile device **14** as a user **12** is conducting the training behaviors **32** as described with respect to process step **410**. The data could be received by an application operating on the user device **14**, or an application operating remotely, for example on a remote server/cloud computing environment **26**. The process continues at process step **520** with extracting time and frequency domain features from the raw data. In an embodiment, the extraction is implemented by dividing the training time period of step **410** into a number of slices "N", and then extracting the data for each slice. It is desirable to make the slices sufficiently small (of short enough time duration) to ensure robust acquisition for the frequency domain content. In an embodiment, a time slice of

5-10 seconds is employed, though it should be appreciated that other values for the time slices are possible and envisioned. In addition, it is advantageous to have each of the slices overlap slightly to ensure that no data is lost at the boundaries of the slices. In an embodiment, a 105 to 50% overlap is employed, though it should be appreciated that other values are possible particularly depending on the number of slices N selected, their duration, the duration of the training period, and the like. The time and frequency domain features are then applied to the machine learning algorithm as depicted at process step **530** to build the behavior models **32** and formulate the local baseline application access model **30**. As described above, this baseline application model **30** may also be aggregated with other baseline application models **30** to create the aggregated baseline application model **42**. Finally, as depicted at process step **540**, the new baseline application access models **30** and or the aggregated baseline application model **42** is provided to the user device **14** include predictions associates with user behaviors **32**. In an embodiment the models include predictions of user gestures on the user device **14** including tap or press, swipe, press and swipe, pinch, and the like.

[0061] The method **400** continues at process step **420** with an authorized user **12***a*, **12***c*, **12***e*, employing the baseline application model **30** or the aggregated baseline application model **42** to initiate a user specific training session. In this instance the baseline model **30**, (or aggregated baseline model **42**) is updated learning further details of a specific authorized user's e.g., **12***a*, **12***c*, **12***e*, behaviors **30**. The behavior models **30** for the particular user **12** are then updated to facilitate the continuous authentication as described herein. In an embodiment, as depicted at process step **430**, an authorized user **12***a*, **12***c*, **12***e* may employ a training app that facilitates capturing specific user behaviors **32** and the learning (teaching and updating) the baseline access model **30**, **42** to form or build a user specific detection model **44**. As described above the training app may require a reduced time and processing executing selected operations and gestures. Once again in operation, the learning/updates are accomplished employing process steps **510-540** to gather dynamic data while a given authorized user e.g., **12***a*, **12***c*, **12***e* is completing the training. Once training is completed, the user specific detection model **44** (FIG. **1**) has been built, and is available for continuous authentication as depicted at process step **450**. It should be appreciated that the training and building of a specific user detection model **44** is accomplished for each authorized user **12***a*, **12***c*, and **12***e*. As a result, there may be a plurality of specific user detection models **44** that are then saved to the user device **14**. In another embodiment, it should be appreciated that building the specific user detection model **44** may include only recording the variations from the baseline user model **30**, **42** rather than necessarily building and storing separate complete user detection models **44** for each authorized user e.g., **12***a*, **12***c*, **12***e*, for predicting a user's action based on the user specific detection model **44**. The prediction is based on building the profiles and models as described above.

[0062] After training, the user detection model(s) **44** are deployed on the user device **14** or on the cloud computing environment **26** for use and may readily be employed to predict if a given user **12** is an authorized user e.g., **12***a*, **12***c*, **12***e*, or anomalous and not authorized e.g. **12***b*, **12***d* based on the observations as depicted at process step **460** In operation, to carry out the process of conducting the method of continuous authentication, the application on the user device **14** continues process steps **510-540** to gather and process dynamic data collected as various users **12** operated the user device **14**. The process **400** then includes comparing the observed behaviors **32** from the data with that of the user authentication model(s) **44** to identify if a particular user **12** is authorized user e.g. **12***a*, **12***c*, **12***e*, or an unauthorized user e.g. **12***b*, **12***d* as described further herein. As data is collected and applied to each of the behavior models, this instance the user authentication model(s) **44** a comparison is continually made as the model(s) learn more of the specific behaviors of the users e.g. **12***a*, **12***c*, **12***e*, or an unauthorized user e.g. **12***b*, **12***d*. As each user **12***a*, **12***c*, **12***e*, or an unauthorized user e.g. **12***b*, **12***d* inputs data, the models generate an outlier score or anomaly score based on how closely the behavior data matches (or how far away from the current model the data is. Outlier scores for various models **44** can be normalized and weighted in different ways and ultimately combined to establish a trust score **34**. For example, in an embodiment, for various behaviors and behavior models, a set of normalized outlier scores from model **1**, model **2** and model **3** be denoted as (O1, O2, O3 . . .). Using a simple weighting scheme, the trust score **34**=w1*O1+w2*O2+w3*O3 . . . . The trust score **34** is then compared with a user or application defined threshold to output as normal or abnormal user. Using a scheme that flags the most anomalous behavior, as an example, the trust score=max(O1, O2, O3), which suggests that if any of the model(s) indicates an anomaly (i.e. an unauthorized user e.g. **12***b*, **12***d*, e.g. **12***b*, **12***d* he behavior and user **12** are flagged as an anomaly. While such an approach is the most conservative and directed to most readily identifying unauthorized users e.g. **12***b*, **12***d*, other schemes could be employed. For example, the trust score could be established that at least two behaviors would have to be identified as anomalous to then flag a user **12** as an unauthorized user e.g. **12***b*, **12***d*.

[0063] The technical effects and benefits of embodiments relate to a method and system for authenticating a user with a mobile device based on the way user accesses, interfaces, and utilizes various mobile applications. Advantageously the described method enables continual, strong and user-friendly context-aware authentication for data protection and service usage control. The method is based on integrating existing service access technologies with mobile device sensors and perception systems using our novel techniques for multi-sensor fusion, multivariate time series classification and segmentation algorithms, risk-based dynamic access control inference engine and context-aware remote management. Uniquely, rather than employing data associated with the individual applications a profile for the user is built from dynamic data, e.g., accelerometer and gyroscope data, as the user employs various applications on the mobile device.

[0064] The present disclosure 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 invention. 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 hard disk, a random access memory (RAM), a read-only memory (ROM), a portable compact disc (CD), a digital versatile disk (DVD), a memory stick, and the like.

[0065] 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. The network may comprise copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers, and the like.

[0066] 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 invention. 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.

[0067] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of scope and breadth of the claims. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one more other features, integers, steps, operations, element components, and/or groups thereof.

[0068] The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the embodiments has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the described embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the claims. The embodiments have been chosen and described in order to best explain the principles of the inventive concept and the practical application, and to enable others of ordinary skill in the art to understand the scope and breadth of the claims and the various embodiments with various modifications as are suited to the particular use contemplated.

1. A method of continuous user authentication on a mobile device, the method comprising:
- establishing a baseline application access model, the baseline application access model based on at least one behavior model of a plurality of behavior models generated based on acquiring dynamic data associated with the mobile device;
- deploying at least one of a training app or a baseline application model to the mobile device;
- generating a user detection model, the user detection model based on at least one baseline application access model and at least one behavior model of the plurality of behavior models updated by dynamic data associated with the mobile device collected while an authorized user employs the mobile device to access an application;
- if the user detection model was remotely generated, deploying the user detection model to the mobile device;
- measuring further dynamic data to predict behaviors in the user detection model while a user operates the mobile device; and
- determining if a user is an authorized user based on how closely measured behaviors match the trained behaviors in the user detection model.

2. The method of claim **1**, wherein at least one behavior model of a plurality of behavior models includes user gestures associated with using the mobile device.

3. The method of claim **1**, wherein the plurality of user gestures associated with using the mobile device includes at least one of a tap to select, a swipe, a scroll, and a pinch.

4. The method of claim **1**, wherein the behavior model of a plurality of behavior models includes: at least one of unlocking the mobile device, entering data into the device, answering a call on the mobile device, patterns with respect to the keystrokes that a certain operator makes to enter input into the device, and biometrics.

5. The method of claim **1**, wherein the biometrics include at least one of heart rate, respiration rate, and skin conductivity.

6. The method of claim **1**, wherein the baseline application access model is updated on a plurality of baseline application models from other users.

7. The method of claim **1**, wherein acquiring dynamic data associated with the mobile device further includes:
- acquiring raw dynamic sensor data from the mobile device for a selected duration;
- extracting time and frequency domain features in the raw dynamic sensor data; and
- building at least one behavior model of a plurality of behavior models by applying extracted time and frequency domain features to a learning algorithm.

8. The method of claim **7**, wherein the dynamic data includes at least one of rotational accelerations, rotational rates, rotation, translational accelerations, translational velocities, and position data, associated with the mobile device.

9. The method of claim **1**, wherein the position data is based on at least one of accelerometer, gyroscope and GPS data.

10. The method of claim **1**, further including that the baseline application access model is an aggregate of a

plurality the baseline application access models associated with a plurality of user devices.

11. The method of claim **10**, wherein the baseline application access model, is aggregated on a remote server based on a plurality the baseline application access models associated with a plurality of user devices.

12. The method of claim **1**, further including that the user detection model, is an aggregate of a plurality user detection models.

13. (canceled)

14. The method of claim **1**, wherein the at least one behavior model is independent of user application touch sensor data.

15. The method of claim **1**, further including establishing a trust score associated with the determining, the trust score providing a weighting of how closely the measured behaviors match the trained behaviors in the user detection model.

16. The method of claim **15**, wherein a trust score greater than a selected threshold indicates a sufficient match for authentication.

17. The method of claim **1**, further including taking security precautions with the user device if the user is identified as not an authorized user.

18. The method of claim **1**, wherein the security precautions include at least one of sounding an alarm, locking the mobile device, placing a call to law enforcement, shutting the mobile device off.

19. The method of claim **1**, further including acquiring data from a wearable device and establishing at least one behavior model of the plurality of behavior models generated based on the data associated with the wearable device.

20. The method of claim **1**, wherein the data associated with the wearable device is biometric data associated with the user.

21. A system for continuous user authentication on a mobile device, the system comprising:

a user device;

a server, the server operably connected to the user device;

at least one of the server and the user device configured to execute a method of continuous user authentication on the mobile device, the method comprising:

establishing a baseline application access model, the baseline application access model based on at least one behavior model of a plurality of behavior models generated based on acquiring dynamic data associated with the mobile device;

deploying at least one of a training app or a baseline application model to the mobile device;

generating user detection model, the user detection model based on at least one baseline application access model and at least one behavior model of the plurality of behavior models updated by dynamic data associated with the mobile device collected while an authorized user employs the mobile device to access an application;

if the user detection model was remotely generated, deploying the user detection model to the mobile device;

measuring further dynamic data to predict behaviors in the user detection model while a user operates the mobile device; and

determining if a user is an authorized user based on how closely measured behaviors match the trained behaviors in the user detection model.

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