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Automating Responses to Authentication Requests Using Unsupervised Computer Learning Techniques

Abstract

Techniques are disclosed relating to automating authentication decisions for a multi- factor authentication scheme based on computer learning. In disclosed embodiments, a mobile device receives a first request corresponding to a factor in a first multi-factor authentication procedure. Based on user input approving or denying the first request, the mobile device sends a response to the first request and stores values of multiple parameters associated with the first request. The mobile device receives a second request corresponding to a factor in a second multi-factor authentication procedure where the second request is for authentication for a different account than the first request. The mobile device automatically generates an approval response to the second request based on performing a computer learning process on inputs that include values of multiple parameters for the second request and the stored values of the multiple parameters associated with the first request. The approval response is automatically generated and sent without receiving user input to automate the second request.

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Background/Summary

PRIORITY CLAIM [0001] The present application is a continuation of U.S. application Ser. No. 17/461,303, entitled “Automating Responses to Authentication Requests Using Unsupervised Computer Learning Techniques,” filed Aug. 30, 2021, which is a continuation of U.S. application Ser. No. 16/025,885, entitled “Automating Responses to Authentication Requests Using Unsupervised Computer Learning Techniques,” filed Jul. 2, 2018 (now U.S. Pat. No. 11,108,764); the disclosures of each of the above-referenced applications are incorporated by reference herein in their entireties.

BACKGROUND
Technical Field
[0002] Embodiments described herein relate to multi-factor authentication and, in particular, to automating responses, on a mobile device, to one or more authentication requests.
Description of the Related Art
[0003] Security of user information in accessing private accounts or services is an ongoing problem for individuals attempting to access these accounts/services on the internet. Recent multi-factor authentication schemes have increased security for user information. In addition to the traditionally required username and password to be input by the user, multi-factor authentication procedures include an additional factor, e.g., to show that a user is in possession of a known device such as a cell phone.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0004] FIGS. **1**A and **1**B are diagrams illustrating exemplary communication between a mobile device and an authentication server in a multi-factor authentication procedure involving automated authentication decisions based on an unsupervised computer learning process, according to some embodiments.
[0005] FIG. **2** is a block diagram illustrating exemplary input parameters to a mobile device from multiple different sources, including environmental parameters and parameters already stored on the mobile device, according to some embodiments.
[0006] FIG. **3** is a block diagram illustrating an exemplary computer learning module that is at least partially supervised and that automates authentication decisions based on a target output space, according to some embodiments.

[0007] FIG. **4** is a flow diagram illustrating an exemplary method for automating authentication decisions for different accounts without user input, according to some embodiments.

[0008] FIG. **5** is a block diagram illustrating an exemplary computing device, according to some embodiments.

DETAILED DESCRIPTION

[0009] Multi-factor authentication schemes are often used by online service providers in an attempt to accurately identify account owners and other users of their online services. For example, one factor may relate to knowledge (e.g., user knowledge of a password). Another example factor may relate to possession (e.g., of a device used to receive a separate code out-of-band). Another example factor may relate to inherency (e.g., a property of a device or user). Multiple factors of a given type (e.g., multiple possession factors that are determined using different devices or techniques) may be used for a given multi-factor authentication procedure.

[0010] As discussed above, one form of multi-factor authentication involves contacting a secondary computing device (e.g., a mobile device) that the user registers with the account upon new account creation. For example, a user may enter typical account credentials (e.g., user identification and password) into an account sign-in user interface (UI) and if the credentials are valid, the server sends a code (e.g., via a short message service) to the registered mobile device (e.g., a mobile phone, tablet computer, wearable device, or other similar device). In this example, the user reads the code from the mobile device and enters it into the UI of the online service. In some embodiments, the use of multi-factor authentication increases the level of security for a user account/service. However, although multi-factor authentication schemes may increase the level of security for user accounts/services, they may decrease the case of access for any individual attempting to access one or more private accounts/services.

[0011] Therefore, in some embodiments, a computer learning process is used to automate authentication decisions for one or more factors in multi-factor authentication schemes to improve case of access while maintaining a high level of security for user accounts/services. As one example, a previously authorized mobile device receives a request for a factor in a multi-factor authentication procedure for an account. In this example, without receiving user input concerning automating responses, an unsupervised computer learning module on the previously-authorized mobile device automates a response to the authentication request based on multiple different parameters received and/or stored on the mobile device. In some embodiments, a computer learning module implements one of the following to perform various functionality described herein: neural networks, ensemble learning, supervised learning, unsupervised learning, deep learning, machine learning, recursive self-improvement, etc.

[0012] Various embodiments of an unsupervised computer learning module are presented herein. The disclosed embodiments may be used in a stand-alone manner or as one automation method for authentication in a multi-factor authentication scheme in order to provide increased security as well as ease of use over other techniques. The disclosed embodiments may, for example, be combined with other computer learning techniques to provide automation of decisions in multi-factor authentication schemes, including at-least-partially unsupervised techniques that allow for user input in certain scenarios. One example of user input includes decisions for values output from a computer learning module that are within a threshold of a desirable target output space (see FIG. **3** description), which may further allow inclusion of other output values within the threshold in future automation decisions by a computer learning module for multi-factor authentication procedures.

[0013] This disclosure initially describes, with reference to FIG. **1**, exemplary automation of authentication decisions in multi-factor authentication schemes. Input parameters to a mobile device are discussed with reference to FIG. **2**. FIG. **3** shows an embodiment of a supervised computer learning module. FIG. **4** illustrates an exemplary method and FIG. **5** shows an exemplary computing device.

Example Authentication Server

[0014] FIGS. **1**A and **1**B are diagrams illustrating exemplary communication between a mobile device and an authentication server in a multi-factor authentication procedure involving automated authentication decisions based on an unsupervised computer learning process, according to some embodiments. In the illustrated embodiment, system **100** includes mobile device **110**, authentication server **120** and devices **130**.

[0015] In FIG. **1**A, mobile device **110** receives user input **140** and environment input(s) **150**. The user input **140** received by the mobile device **110** may include but is not limited to one or more of the following: application activity, short message service (SMS) messaging activity, frequency of login, unlock information (e.g., a passcode, biometric information, etc.), and/or other personally identifiable information (PII). Environmental input may include, but is not limited to one or more of the following: time of day, proximity to other devices, biometric information from a wearable device, known user wearing a wearable device, whether a wearable device is unlocked, location of mobile device **110**, location of devices in proximity to the mobile device **110**, etc.

[0016] In the illustrated embodiment, one or more devices **130** request authentication of a user from authentication server **120** (e.g., based on a user attempting to access an account on one of the devices) and the authentication server **120** communicates with mobile device **110** for a factor in the multi-factor authentication process for the user. In the illustrated embodiment, mobile device **110** includes unsupervised computer learning module **112**. In the illustrated embodiment, the unsupervised computer learning module **112** determines whether to send automatic response(s) **160** to authentication server **120**. (Note that the user may be prompted for a response in instances where module **112** does not provide an automatic response). In some embodiments, the unsupervised computer learning module stores parameter values based on user input **140** and/or environmental input(s) **150**. In some embodiments, the parameter values may be stored in a processed format. In some embodiments, module **112** sends automatic response(s) **160** to authentication server based on past and/or current parameter values corresponding to one or more inputs **140** and/or input(s) **150**. Based on responses from mobile device **110** (and/or a device **130**), the authentication server **120** may authenticate the user.

[0017] As used herein, the term “unsupervised computer learning” refers to situations where the user of a mobile device does not indicate to automate decisions or indicate whether unsupervised decisions made by the computer learning process are correct or not. That is, in some embodiments, the unsupervised computer learning process learns when to automate on its own, without user input. One example of unsupervised computer learning involves the module clustering groups of one or more parameters (e.g., frequency of login, wireless signatures, etc.) based on an association with a valid user logging into one or more accounts. In some embodiments, the unsupervised computer learning module on one or more mobile devices becomes unique to the mobile device it is stored on due to training based on different values for various input parameters to the one or more mobile devices. In some embodiments, the learning module may be transferred to another device, e.g., when the user upgrades their mobile phone. In some embodiments, the entire process from receiving a request from the authentication server **120** to sending an automated response from the mobile device **110** is unsupervised.

[0018] In some embodiments, all or a portion of the unsupervised computer learning module is implemented as program code stored on a secure circuit. A secure circuit may limit the number of ways that the stored program code may be accessed (e.g., by requiring a secure mailbox mechanism). Examples of secure circuits include the secure enclave processor (SEP) and the trusted execution environment (TEE) processor. In some embodiments, an SEP or a TEE processor is used to store data securely, e.g., by encrypting stored data and by limiting access to itself (e.g., the SEP or TEE processor are isolated from the main processor on the mobile device).

[0019] FIG. **1**B is a communications diagram illustrating exemplary messages between the authentication server **120** and mobile device **110**, according to some embodiments. At **132**, in the illustrated embodiment, authentication server **120** receives requests from one or more devices requesting authentication in order to access an account. In some embodiments, the requests received at block **132** are from mobile device **110** (e.g., device **130** and device **110** may be the same device). At **124**, in the illustrated embodiment, authentication server **120** sends a first request in a first multi-factor authentication procedure. At **114**, in the illustrated embodiment, mobile device **110** sends a response to the first request based on user input. In some embodiments, the response at **114** does not include user input specifying whether to automate future authentication requests.

[0020] At **126**, in the illustrated embodiment, authentication server **120** sends a second request in a second multi-factor authentication procedure to mobile device **110**. In some embodiments, the request sent at **126** is for authentication of the user for a different account than the request sent at **124**. At **116**, in the illustrated embodiment, mobile device **110** automatically sends a response to authentication server **120** based on a decision from the unsupervised computer learning module, without requesting or receiving any user input associated with the second request.

[0021] In some embodiments, the request that is being automated on the mobile device **110** is for two different accounts. In some embodiments, the two different accounts (e.g., account A and account B) are for two different services (e.g., an email service and an online shopping service). In some embodiments, the two different accounts (e.g., a personal account and a business account) are for the same service (e.g., an email service). In some embodiments, two different requests, for which at least one response is automated on the mobile device **110**, are for the same account and for the same service.

[0022] Various techniques for automating responses for factors in multi-factor authentication schemes are discussed in previously filed U.S. patent application Ser. No. 14/849,312, filed on Sep. 9, 2015. In the previously filed application, automating authentication decisions is performed after user input is received indicating that future authentication decisions should be automated. In disclosed embodiments, a computer learning process is used to automate decisions for one or more factors in multi-factor authentication schemes without receiving any input from a user regarding automation. Further, in disclosed embodiments, an unsupervised computer learning process is used to automate authentication decisions on a mobile device for different accounts/services that the user of the mobile device is attempting to login to/access.

[0023] As used herein, the term “module” refers to circuitry configured to perform specified operations or to physical non-transitory computer readable media that store information (e.g., program instructions) that instructs other circuitry (e.g., a processor) to perform specified operations. Modules may be implemented in multiple ways, including as a hardwired circuit or as a memory having program instructions stored therein that are executable by one or more processors to perform the operations. A hardware circuit may include, for example, custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like. A module may also be any suitable form of non-transitory computer readable media storing program instructions executable to perform specified operations.

Example Parameters

[0024] FIG. **2** is a block diagram illustrating exemplary input parameters to a mobile device from multiple different sources, including environmental parameters and parameters already stored on the mobile device, according to some embodiments. In the illustrated embodiment, mobile device **110** receives user input **140** and information from wearable device **220**, other mobile device **230**, vehicle **240**, and personal computer **250**.

[0025] Mobile device **110**, in the illustrated embodiment, stores values for the following parameters: time of day **214**, frequency of login **216**, and personally identifiable information (PII) **218**. In some embodiments, time of day **214** is received in one or more formats (e.g., a different time zone depending on location, **24**-hour time, coordinated universal time (UTC), etc.). In some embodiments, frequency of login **216** information includes the number of times the mobile device user logs into: the mobile device, one or more applications, one or more accounts, one or more services, a set of multiple different accounts, etc. In some embodiments, the frequency of login **216** is related to the time of day **214**. For example, in some embodiments, the frequency of login **216** information is determined for specified time intervals (e.g., 10 am to 2 pm), for certain days in a week (e.g., only weekdays), over multiple intervals of different lengths (e.g., the last hour or three hours), etc. In some embodiments, PII **218** includes information such as the user's: name, date of birth, biometric records, relatives' names, medical information, employment history, etc. In some embodiments, PII **218** is stored on mobile device **110** and is not available to authentication server **120**. In these embodiments, automating decisions based on this information at the mobile device may improve automation accuracy, relative to automation techniques at authentication server **120**.

[0026] In some embodiments, parameters **214**, **216**, and **218** are stored internally on mobile device **110** in the format they are received or determined. In some embodiments, processed values (e.g., vectors) may be stored based on these parameters, e.g., after processing by module **112**.

[0027] As discussed above, certain PII may not be available on the server side. Including PII from the mobile device **110** in server-side authentication decisions would require sending this information from the mobile device to the authentication server **120**. This may be undesirable because of the sensitivity of such information and because of regulation. For example, data privacy regulations may specify that PII should not be transmitted to any other computing devices (e.g., the information must remain on the device it originated from). Therefore, it may be advantageous to keep PII securely stored on device **110** to comply with such regulations. Therefore, in some disclosed embodiments, automation decisions are made on mobile device **110**. In these embodiments, PII **218** values may never leave mobile device **110** and are used by unsupervised computer learning module **112** in automating authentication decisions.

[0028] In the illustrated embodiment, mobile device **110** receives information **222** from wearable device **220**. In the illustrated embodiment, information **222** indicates whether device **220** is currently being worn. In addition, in the illustrated embodiment, information **222** indicates whether a known user (e.g., the user of the mobile device **110**) is wearing device **220**. In the illustrated embodiment, information **222** indicates whether or not device **220** is unlocked. In various embodiments, any combination of the three sets of information contained in information **222** from wearable device **220** may be stored on mobile device **110** and processed by module **112**. Although three status indicators are shown in information **222** for purposes of illustration, one or more of these indicators may be omitted and/or other indicators may be included. The illustrated examples of information from wearable device **220** are not intended to limit the scope of the present disclosure.

[0029] In the illustrated embodiment, mobile device **110** receives wireless signature(s) **228** from devices **220** and **230**, vehicle **240**, and personal computer **250**. In some embodiments, a wireless signature from one or more of these sources is a Bluetooth low energy (BLE) signature, a WLAN signature, a cellular signature, or a near-field communication (NFC) signature. A wireless signature may include information that is detectable before and/or after connecting with a corresponding device. Further, a wireless signature may include information that is intentionally transmitted by the corresponding device (e.g., a transmitted identifier such as a MAC address) and other types of information (e.g., wireless characteristics of the device related to its physical configuration). In some embodiments, BLE beacon devices transmit a universally unique identifier that informs mobile device **110** that one or more devices are nearby, without connecting, e.g., through BLE, to these devices. In some embodiments, NFC signatures involve short-range radio waves that allow mobile device **110** to determine that another NFC device is a short distance away.

[0030] In some embodiments, a wireless signature from a personal computer **250** informs mobile device **110** that it is at the residence of the user (e.g., the mobile device is nearby their desktop PC which is inside their residence). In some embodiments, a wireless signature **228** from vehicle **240** informs mobile device **110** that it is near vehicle **240**, which may be an indicator that the device has not been stolen. In some embodiments, a wireless signature **228** from other mobile device **230** informs mobile device **110** that it is near another commonly used device (e.g., if device **230** is a tablet owned by the user of mobile device **110**). In various embodiments, the values of wireless signatures from one or more devices are used by a computer learning module to determine whether to automate one or more authentication decisions in a multi-factor authentication procedure. In disclosed embodiments, mobile device **110** may not know the type or identification of a device whose signature it recognizes, but may simply recognize whether the signature is present or not during authenticating procedures, which may be used as an automation criterion. In some embodiments, if mobile device **110** detects wireless signatures from multiple known devices at the same time (e.g., from wearable device **220** and vehicle **240**), the unsupervised computer learning module **112** may be more likely to automate authentication decisions.

Example With Partially-Supervised Computer Learning Module

[0031] Various embodiments of an unsupervised computer learning process are discussed above. However, as noted above, unsupervised computer learning techniques may be combined with other computer learning techniques to provide automation decisions in multi-factor authentication schemes. In particular, a user may be asked for inputs in certain circumstances where automation should likely be performed but cannot be determined with a threshold degree of certainty. In some embodiments, the system requests input from a user for certain values output from the unsupervised computer learning module that are within a threshold distance from a desirable target output space.

[0032] In some embodiments, a multi-factor authentication procedure uses an unsupervised computer learning mode in automating authentication decisions for the entire procedure. However, in some embodiments, automation for a multi-factor authentication procedure reverts to a supervised mode in certain circumstances (e.g., for uncertain output values).

[0033] FIG. **3** is a block diagram illustrating an exemplary supervised computer learning module that automates authentication decisions based on a target output space, according to some embodiments. In the illustrated embodiment, system **300** includes mobile device **110** and mobile device user **330**.

[0034] In the illustrated embodiment, mobile device **110** includes supervised computer learning module **320** with target output space **310**. In the illustrated embodiment, target output space **310** is shown outside of module **320** for discussion purposes. However, in some embodiments, the dimensions of target output space **310** are stored inside module **320** and module **320** checks outputs internally. Note that output space **310** may be a multi-dimension space and module **320** may output a vector in the space. This type of output may be typical for neural networks, for example, but similar techniques may be used for other types of computer learning algorithms with different types of outputs. The embodiment of FIG. **3** is shown for purposes of illustration and is not intended to limit the type of computer learning used in other embodiments.

[0035] In the illustrated embodiment, supervised computer learning module **320** outputs vectors **322** (i.e., values A, B, and C) based on the automation parameter values received from mobile device **110**. In some embodiments, supervised computer learning module **320** evaluates values **322** as they relate to target output space **310**. At **312**, in the illustrated embodiment, the dotted outline represents a threshold distance from the target output space **310**. In the illustrated embodiment, value A is outside space **310**, value B is within a threshold distance from space **310**, and value C is inside space **310**.

[0036] At **324**, in the illustrated embodiment, supervised computer learning module **320** sends a request to mobile device user **330** for input concerning computer learning output value B. At **334**, in the illustrated embodiment, user **330** sends a decision to module **320** for value B. In the illustrated embodiment, at **326**, module **320** updates the target output space **310** based on the decision for value B received at **334** from mobile device user **330**. Note that the decision **334** may not include input from the user for future automation but may only include a decision for one particular value as requested by module **320**.

[0037] In some embodiments supervised computer learning techniques may be implemented, in addition to or in place of the unsupervised techniques discussed herein. In some embodiments, supervised computer learning involves a set of “training” values. For example, a supervised computer learning module is provided a predetermined set of values for which the correct outputs are known. In this example, based on those values, the supervised computer learning process generates outputs and compares them with the set of training values. If the generated outputs match the training outputs (e.g., a direct match or within some threshold), the supervised computer learning process may be considered trained (although additional training may continue afterwards). If the values are different, the supervised computer learning process adjusts one or more internal parameters (e.g., adjusting weights of neural network nodes, adjust rules of a rule-based algorithm, etc.). Note that the adjustments to target output space **310** discussed above are supervised in the sense that user input is required, but does not actually result in training of module **320**, but merely adjusting target outputs. In other embodiments, user input may be used to train module **320** in a supervised fashion.

Exemplary Methods

[0038] FIG. **4** illustrates an exemplary method for automating authentication decisions for different accounts without user input, according to some embodiments. The method shown in FIG. **4** may be used in conjunction with any of the computer circuitry, systems, devices, elements, or components disclosed herein, among other devices. In various embodiments, some of the method elements shown may be performed concurrently, in a different order than shown, or may be omitted. Additional method elements may also be performed as desired.

[0039] At **410**, in the illustrated embodiment, a mobile phone receives a first request, wherein the first request corresponds to a factor in a first multi-factor authentication procedure.

[0040] At **420**, in the illustrated embodiment, the mobile device sends a response to the first request based on user input approving or denying the first request and stores values of multiple parameters associated with the first request.

[0041] At **430**, in the illustrated embodiment, the mobile device receives a second request, wherein the second request corresponds to a factor in a second multi-factor authentication procedure, wherein the second request is for authentication for a different account than the first request. In some embodiments, the different account for the second request is for a different service than the account for the first request.

[0042] At **440**, in the illustrated embodiment, an unsupervised computer learning module on the mobile device automatically generates an approval response to the second request based on performing a computer learning process on inputs that include values of multiple parameters for the second request and the stored values of the multiple parameters associated with the first request, wherein the approval response is automatically generated without receiving user input to automate the second request. In some embodiments, the multiple parameters include a frequency of login parameter that indicates how often the user of the mobile device logs into a set of one or more accounts. In some embodiments, the multiple parameters include a wearable device parameter that indicates whether a wearable device is being worn by the user of the mobile device and whether the wearable device is unlocked. In some embodiments, the multiple parameters include one or more parameters that indicate personally identifiable information (PII) that is stored on the mobile device that is not shared with other devices. In some embodiments, the multiple parameters include a wireless signature parameter based on wireless signatures of one or more nearby devices. In some embodiments, the computer learning process is an unsupervised computer learning process. In some embodiments, the wireless signature is a Bluetooth Low Energy (BLE) signature. In some embodiments, program code for the computer learning process is stored on a secure circuit.

[0043] In some embodiments, the computer learning process outputs one or more values and a determination whether to automate is based on whether one or more values output from the computer learning process are in a target output space. In some embodiments, the computer learning process requests user input indicating whether or not to automate in response to determining that the one or more values are outside the target output space but within a threshold distance from the target output space. In some embodiments, the computer learning process updates the target output space in response to the user selecting to automate. In other embodiments, the computer learning process may train itself based on explicit user input.

[0044] At **450**, in the illustrated embodiment, the mobile device sends the automatically generated approval response.

[0045] In some embodiments, an authorization decision is based at least in part on detecting close proximity or physical contact of one or more devices, e.g., using short-range wireless technology. In some embodiments, the short-range wireless technology is near-field communication (NFC). In some embodiments, short-range wireless technology is used for one or more factors in a multi-factor authentication process. In a multi-factor authentication procedure, a factor relating to possession and intentionality (possession of one or more of the devices in short-range communication and intention to move the devices near each other) may be used as an additional factor to knowledge (e.g., of a username and password) and possession (e.g., using the automated techniques discussed herein), in various embodiments. This example embodiment may be referred to as three-factor authentication (e.g., with two possession-related factors and one knowledge-related factor) or two-factor authentication (e.g., grouping the intentional and automated possession techniques as a single factor).

[0046] A short-range wireless device may be embedded in a user's clothing, for example. In this example, upon receiving a request for a factor in a multi-factor authentication process, the user taps the mobile device against their short-range wireless enabled clothing. The device may provide limited-use passcodes or other identifying data that the mobile device then provides to the authentication server. The authentication server may, in certain scenarios, authenticate only if this short-range wireless exchange is confirmed. In this example, the user is intentionally employing short-range wireless technology for a factor (e.g., a possession factor) in a multi-factor authentication procedure.

[0047] In some embodiments, using short-range wireless technology in a multi-factor authentication procedure advantageously improves the level of security for certain high-security transactions. Note that short-range wireless technology may be used for a factor even when disclosed automation techniques are not involved (e.g., user input is received for the factor) in a multi-factor authentication procedure. However, in some embodiments, short-range wireless communications (e.g., NFC-enabled clothing) are used as another input parameter to the computer learning process.

Exemplary Computing Device

[0048] Turning now to FIG. **5**, a block diagram of a computing device (which may also be referred to as a computing system) **510** is depicted, according to some embodiments. Computing device **510** may be used to implement various portions of this disclosure. Computing device **510** is one example of a device that may be used as a mobile device, a server computer system, a client computer system, or any other computing system implementing portions of this disclosure.

[0049] Computing device **510** may be any suitable type of device, including, but not limited to, a personal computer system, desktop computer, laptop or notebook computer, mobile phone, mainframe computer system, web server, workstation, or network computer. As shown, computing device **510** includes processing unit **550**, storage subsystem **512**, and input/output (I/O) interface **530** coupled via interconnect **560** (e.g., a system bus). I/O interface **630** may be coupled to one or more I/O devices **540**. Computing device **510** further includes network interface **532**, which may be coupled to network **520** for communications with, for example, other computing devices.

[0050] Processing unit **550** includes one or more processors, and in some embodiments, includes one or more coprocessor units. In some embodiments, multiple instances of processing unit **550** may be coupled to interconnect **560**. Processing unit **550** (or each processor within processing unit **550**) may contain a cache or other form of on-board memory. In some embodiments, processing unit **550** may be implemented as a general-purpose processing unit, and in other embodiments it may be implemented as a special purpose processing unit (e.g., an ASIC). In general, computing device **510** is not limited to any particular type of processing unit or processor subsystem.

[0051] As used herein, the terms "processing unit" or "processing element" refer to circuitry configured to perform operations or to a memory having program instructions stored therein that are executable by one or more processors to perform operations. Accordingly, a processing unit may be implemented as a hardware circuit implemented in a variety of ways. The hardware circuit may include, for example, custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A processing unit may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like. A processing unit may also be configured to execute program instructions or computer instructions from any suitable form of non-transitory computer-readable media to perform specified operations.

[0052] Storage subsystem **512** is usable by processing unit **550** (e.g., to store instructions executable by and data used by processing unit **550**). Storage subsystem **512** may be implemented by any suitable type of physical memory media, including hard disk storage, floppy disk storage, removable disk storage, flash memory, random access memory (RAM-SRAM, EDO RAM, SDRAM, DDR SDRAM, RDRAM, etc.), ROM (PROM, EEPROM, etc.), and so on. Storage subsystem **512** may consist solely of volatile memory in some embodiments. Storage subsystem **512** may store program instructions executable by computing device **510** using processing unit **550**, including program instructions executable to cause computing device **510** to implement the various techniques disclosed herein.

[0053] I/O interface **530** may represent one or more interfaces and may be any of various types of interfaces configured to couple to and communicate with other devices, according to various embodiments. In some embodiments, I/O interface **530** is a bridge chip from a front-side to one or more back-side buses. I/O interface **530** may be coupled to one or more I/O devices **540** via one or more corresponding buses or other interfaces. Examples of I/O devices include storage devices (hard disk, optical drive, removable flash drive, storage array, SAN, or an associated controller), network interface devices, user interface devices or other devices (e.g., graphics, sound, etc.).

[0054] It is noted that the computing device of FIG. **5** is one embodiment for demonstrating disclosed concepts. In other embodiments, various aspects of the computing device may be different. For example, in some embodiments, additional components, or multiple instances of the illustrated components may be included.

[0055] This specification includes references to "one embodiment," "other embodiments," "some embodiments," or "an embodiment." The appearances of these phrases do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

[0056] Various units, circuits, or other components may be described or claimed as "configured to" perform a task or tasks. In such contexts, "configured to" is used to connote structure by indicating that the units/circuits/components include structure (e.g., circuitry) that performs the task or tasks during operation. As such, the unit/circuit/component can be said to be configured to perform the task even when the specified unit/circuit/component is not currently operational (e.g., is not on). The units/circuits/components used with the "configured to" language include hardware—for example, circuits, memory storing program instructions executable to implement the operation, etc. Reciting that a unit/circuit/component is "configured to" perform one or more tasks is expressly intended not to invoke 35 U.S.C. § 112(f) for that unit/circuit/component.

[0057] As used herein, the term "based on" is used to describe one or more factors that affect a determination. This term does not foreclose the possibility that additional factors may affect the determination. That is, a determination may be solely based on specified factors or based on the specified factors as well as other, unspecified factors. Consider the phrase “determine A based on B.” This phrase specifies that B is a factor used to determine A or that affects the determination of A. This phrase does not foreclose that the determination of A may also be based on some other factor, such as C. This phrase is also intended to cover an embodiment in which A is determined based solely on B. As used herein, the phrase “based on” is synonymous with the phrase “based at least in part on.”

[0058] Although specific embodiments have been described above, these embodiments are not intended to limit the scope of the present disclosure, even where only a single embodiment is described with respect to a particular feature. Examples of features provided in the disclosure are intended to be illustrative rather than restrictive unless stated otherwise. The above description is intended to cover such alternatives, modifications, and equivalents as would be apparent to a person skilled in the art having the benefit of this disclosure.

[0059] The scope of the present disclosure includes any feature or combination of features disclosed herein (either explicitly or implicitly), or any generalization thereof, whether or not it mitigates any or all of the problems addressed herein. Accordingly, new claims may be formulated during prosecution of this application (or an application claiming priority thereto) to any such combination of features. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the appended claims.

Claims

1. A method, comprising: receiving, by a server system, a login request, wherein the login request includes a first factor in a multi-factor authentication (MFA) procedure; requesting, by the server system in response to the login request, a response from a mobile device to include a second factor in the MFA procedure; receiving, by the server system, the requested response token from the mobile device. wherein the response token comprises: an MFA token automatically generated based on data provided by a machine learning module at the mobile device without receiving input from a user of the mobile device; and one or more context values of the mobile device: and determining, by the server system, that the received MFA token is valid and that at least one of the one or more context values complies with a login policy; and sending, by the server system, an approval response to the login request.

2. The method of claim 1, wherein at least one of the context values is one of: type of device, proximity to another device, location of device, time of day, current weather, and signal strength.

3. The method of claim 1, further comprising, prior to receiving the login request: training, by the server system a plurality of machine learning modules using different context values of a plurality of mobile devices; and transmitting, by the server system to the mobile device, a trained machine learning module that is unique to the mobile device based on the training of the trained module being based on a plurality of context values of the mobile device.

4. The method of claim 1, wherein the data provided by the machine learning module seeds the requested response from the mobile device.

5. The method of claim 1, wherein the data provided by the machine learning module comprises one or more parameters for the response by the mobile device.

6. The method of claim 5, wherein the one or more parameters are context values of the mobile device.

7. The method of claim 1, wherein the one or more context values include a frequency of login parameter that indicates how often the user of the mobile device logs into a set of one or more accounts.

8. The method of claim 1, wherein the one or more context values include a wearable device parameter that indicates whether a wearable device is being worn by the user of the mobile device and whether the wearable device is unlocked.

9. A non-transitory computer-readable medium having instructions stored thereon that are capable of causing a server computing system to implement operations comprising: receiving a login request, wherein the login request includes a first factor in a multi-factor authentication (MFA) procedure; evaluating data associated with the login request based on a login policy; requesting, in response to the login request, a response from a mobile device to include a second factor in the MEA procedure, the requesting comprising sending MFA data from the server computing system to the mobile device indicating a required level of security based on the login policy; receiving the requested response token from the mobile device, wherein the response token is generated at the mobile device based on output of a machine learning module at the mobile device according to the MFA data and without receiving input from a user of the mobile device; and sending an approval response based on the response token.

10. The non-transitory computer-readable medium of claim 9, wherein the response token includes one or more context values of the mobile device, and wherein the one or more context values include a wearable device parameter that indicates whether a wearable device is being worn by the user of the mobile device and whether the wearable device is unlocked.

11. The non-transitory computer-readable medium of claim 9, wherein the MFA data includes one or more context values that indicate personally identifiable information (PII) that is stored on the mobile device and is not shared with other devices.

12. The non-transitory computer-readable medium of claim 9, wherein the output of the machine learning module at the mobile device seeds the requested response from the mobile device.

13. The non-transitory computer-readable medium of claim 12, wherein the MFA data comprises one or more context parameters to be used by the machine learning module, and wherein a context parameter is one of: type of device, proximity to another device, location of device, time of day, current weather, and signal strength.

14. A system, comprising: receiving a login request, wherein the login request includes a first factor in a multi-factor authentication (MFA) procedure; requesting, in response to the login request, a response from a mobile device to include a second factor in the MEA procedure; receiving the requested response token from the mobile device, wherein the response token comprises: an MFA token automatically generated at the mobile device based on output of a machine learning module without receiving input from a user of the mobile device to automate the response token; and one or more context values of the mobile device: and sending a response based on the received response token.

15. The system of claim 14, wherein at least one of the context values is one of: type of device, proximity to another device, location of device, time of day, current weather, and signal strength.

16. The system of claim 14, wherein the output of the machine learning module seeds the requested response from the mobile device.

17. The system of claim 14, wherein the output of the machine learning module comprises one or more parameters for the response by the mobile device, and wherein the one or more parameters are context values of the mobile device.

18. The system of claim 14, wherein the machine learning module at the mobile device is unique to the mobile device based on training of the machine learning module including training on a plurality of previous context values of the mobile device.

19. The system of claim 14, wherein the one or more context values include a wearable device parameter that indicates whether a wearable device is being worn by the user of the mobile device and whether the wearable device is unlocked.

20. The system of claim 14, further comprising: transmitting to a new mobile device utilized by the user of the mobile device, the machine learning module trained on a plurality of previous context values of the mobile device.