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(54) TEST CASE GENERATION USING GENERATING ARTIFICIAL INTELLIGENCE

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(57) **ABSTRACT**

An example operation may include one or more of receiving a request to test a software program from a user device, the request comprising a description of requirements of the software program, generating a plurality of testing elements based on execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases, generating a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model, and storing the test case within a storage device.

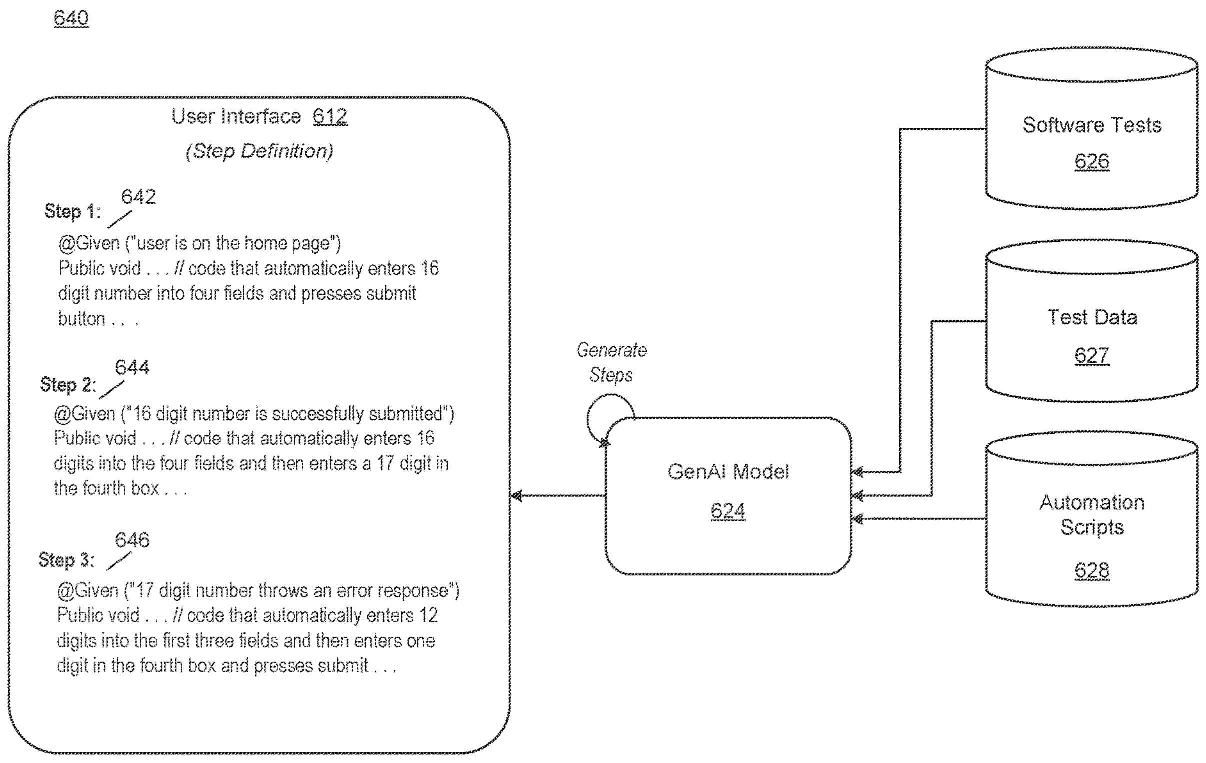

640
User Interface 612
(Step Definition)
Step 1: 642
@Given ("user is on the home page")
Public void . . . // code that automatically enters 16 digit number into four fields and presses submit button . . .
Step 2: 644
@Given ("16 digit number is successfully submitted")
Public void . . . // code that automatically enters 16 digits into the four fields and then enters a 17 digit in the fourth box . . .
Step 3: 646
@Given ("17 digit number throws an error response")
Public void . . . // code that automatically enters 12 digits into the first three fields and then enters one digit in the fourth box and presses submit . . .
Generate Steps
GenAI Model 624
Software Tests 626
Test Data 627
Automation Scripts 628

FIG. 1A

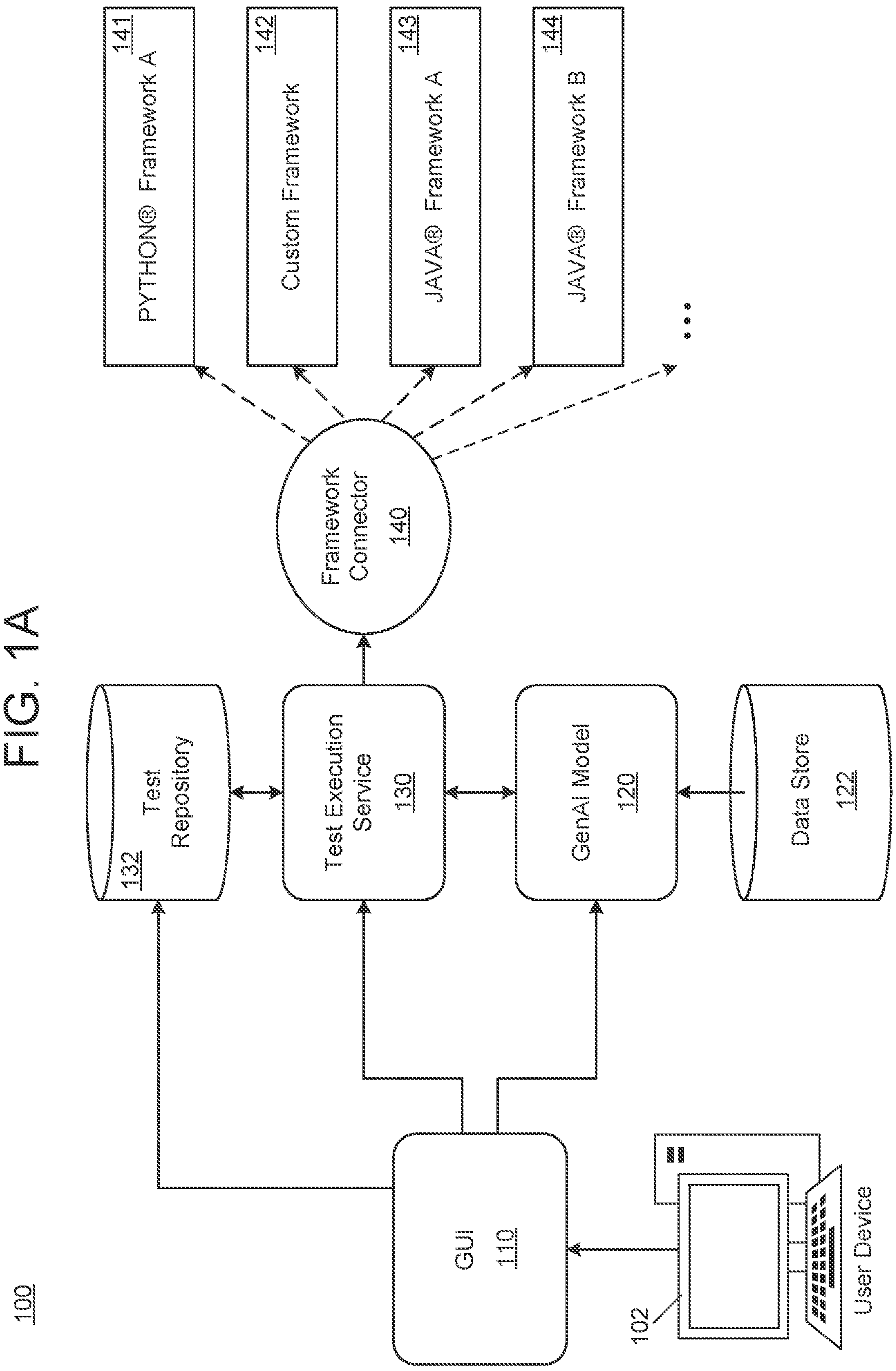
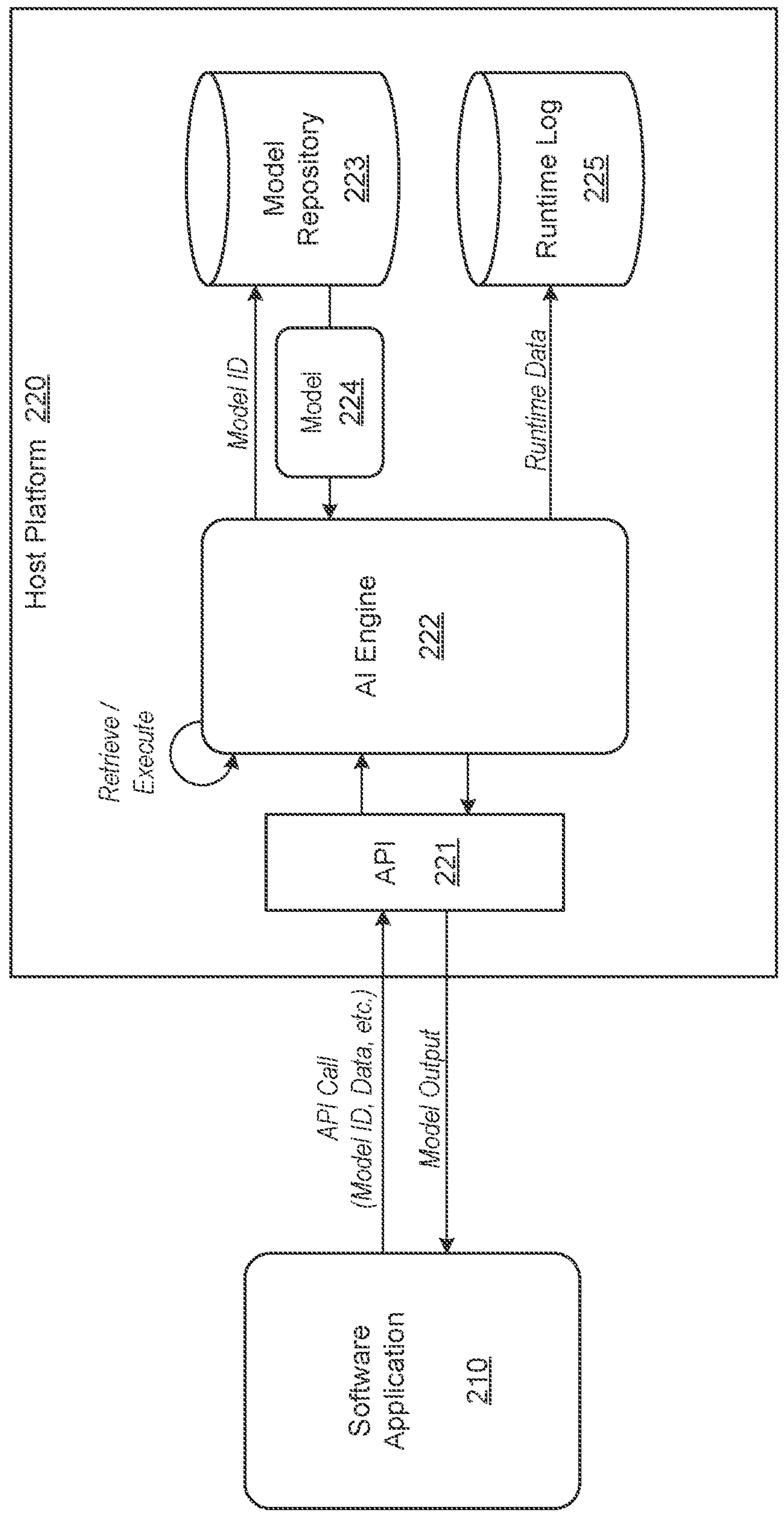

100
GUI 110
102
User Device
Test Repository 132
Test Execution Service 130
GenAI Model 120
Data Store 122
Framework Connector 140
PYTHON® Framework A 141
Custom Framework 142
JAVA® Framework A 143
JAVA® Framework B 144
...

FIG. 1B

150

152	154 Input	156 Expected Result	158 Actual Result	160
Verify Four Text Boxes on the GUI to Accommodate 16 Digit Card Number	Enter 4 Digits in a Text Box and Check for Automatic Movement of Cursor to Next Box	Once the 4 Digits are Entered in the Text Box, the Cursor Should Automatically Move to the Next Text Box		Pass / Fail
	Check with a Valid 16 Digit Card Number	Four Text Boxes to be Displayed and 16 Digits to Input with 4 Digits to be Input in Each Text Box		Pass / Fail
	Check with an Invalid 20 Digit Card Number	Four Text Boxes to be Displayed and 16 Digits to Input with 4 Digits to be Input in Each Text Box, the User should not be able to enter the last 4 Digits		Pass / Fail
	Check with an Invalid 13 Digit Card Number	Four Text Boxes with 13 Digits including with 4 Digits in the first 3 Text Boxes and one digit in last box. An error message should be displayed		Pass / Fail

FIG. 2


200
Host Platform 220
Model Repository 223
Runtime Log 225
Model ID
Model 224
Runtime Data
AI Engine 222
Retrieve / Execute
API 221
API Call (Model ID, Data, etc.)
Model Output
Software Application 210

300A

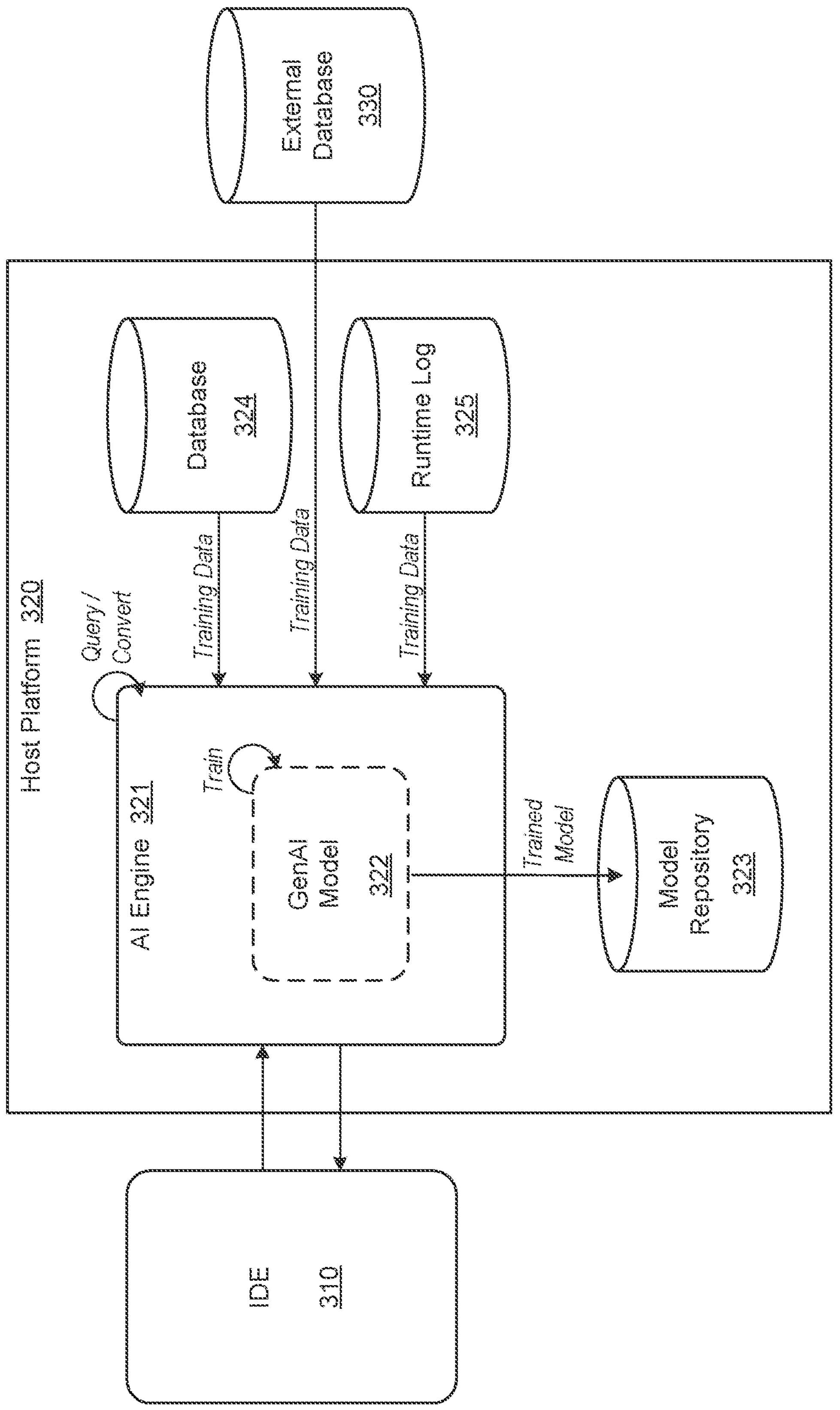
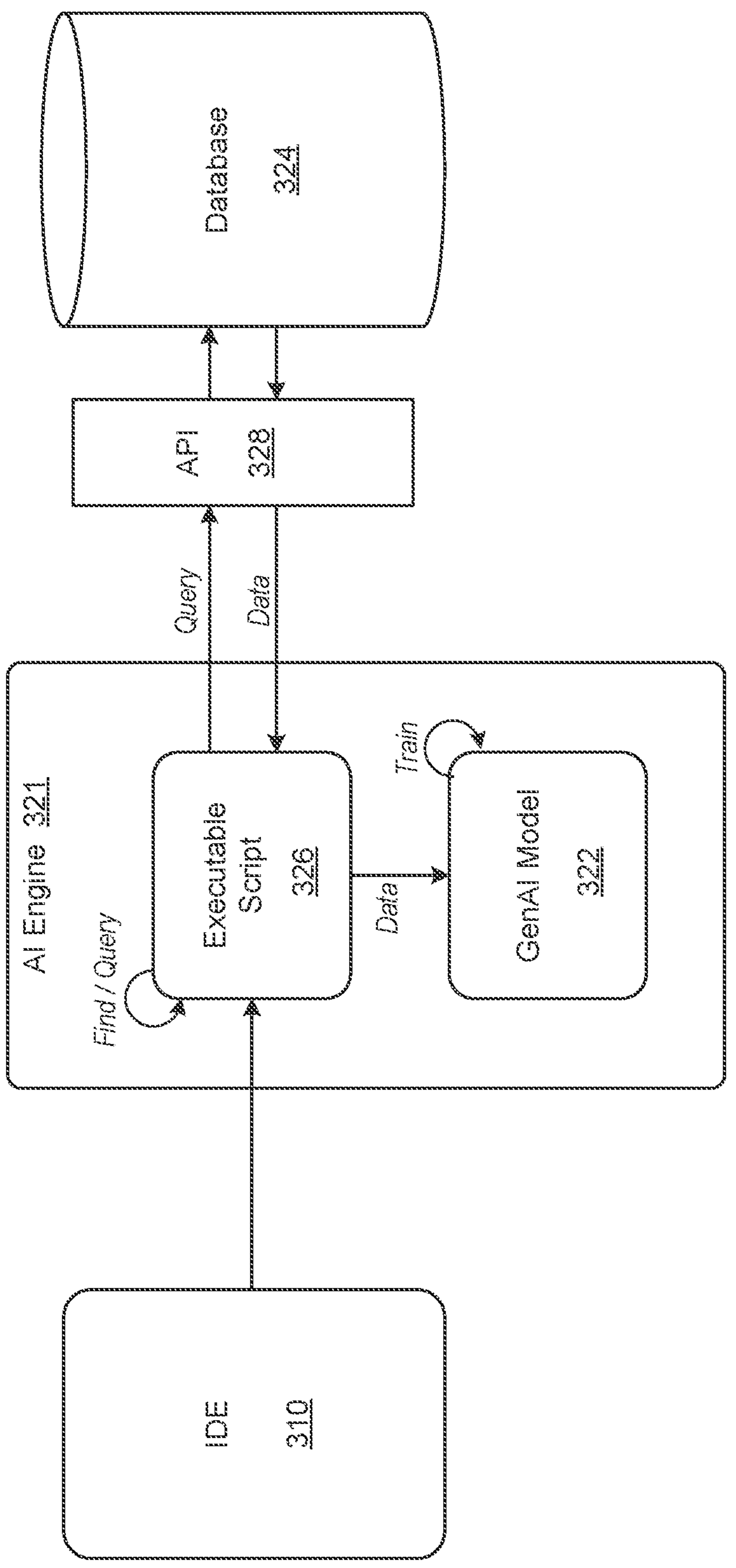

External Database 330
Host Platform 320
Database 324
Runtime Log 325
Query / Convert
Training Data
Training Data
Training Data
AI Engine 321
Train
GenAI Model 322
Trained Model
Model Repository 323
IDE 310

FIG. 3A

FIG 3B

300B


Database 324
API 328
Query
Data
AI Engine 321
Executable Script 326
Find / Query
Data
Train
GenAI Model 322
IDE 310

300C

FIG. 3C

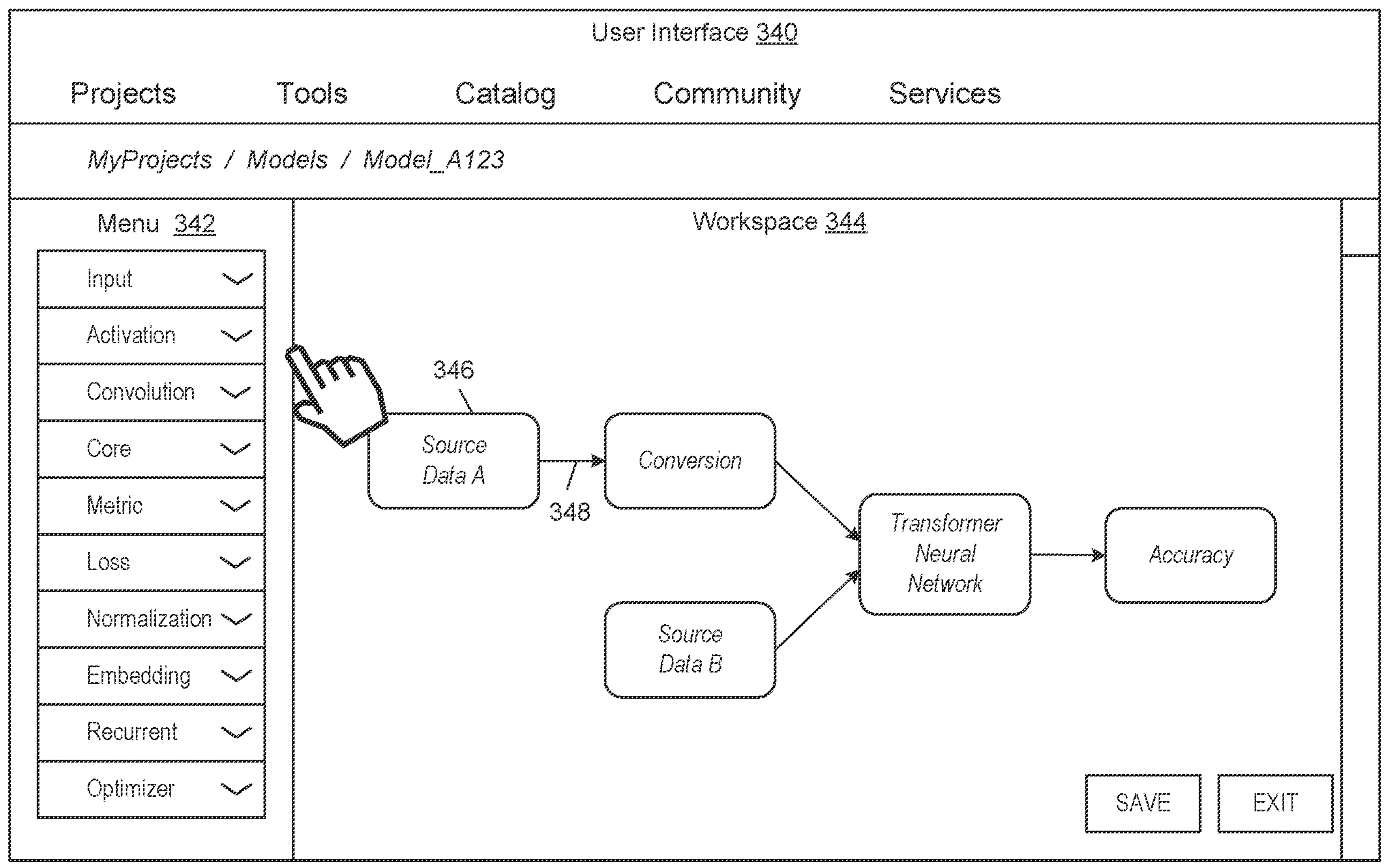

User Interface 340
Projects
Tools
Catalog
Community
Services
MyProjects / Models / Model_A123
Menu 342
Input
Activation
Convolution
Core
Metric
Loss
Normalization
Embedding
Recurrent
Optimizer
Workspace 344
346
Source Data A
348
Conversion
Source Data B
Transformer Neural Network
Accuracy
SAVE
EXIT

FIG. 4

400

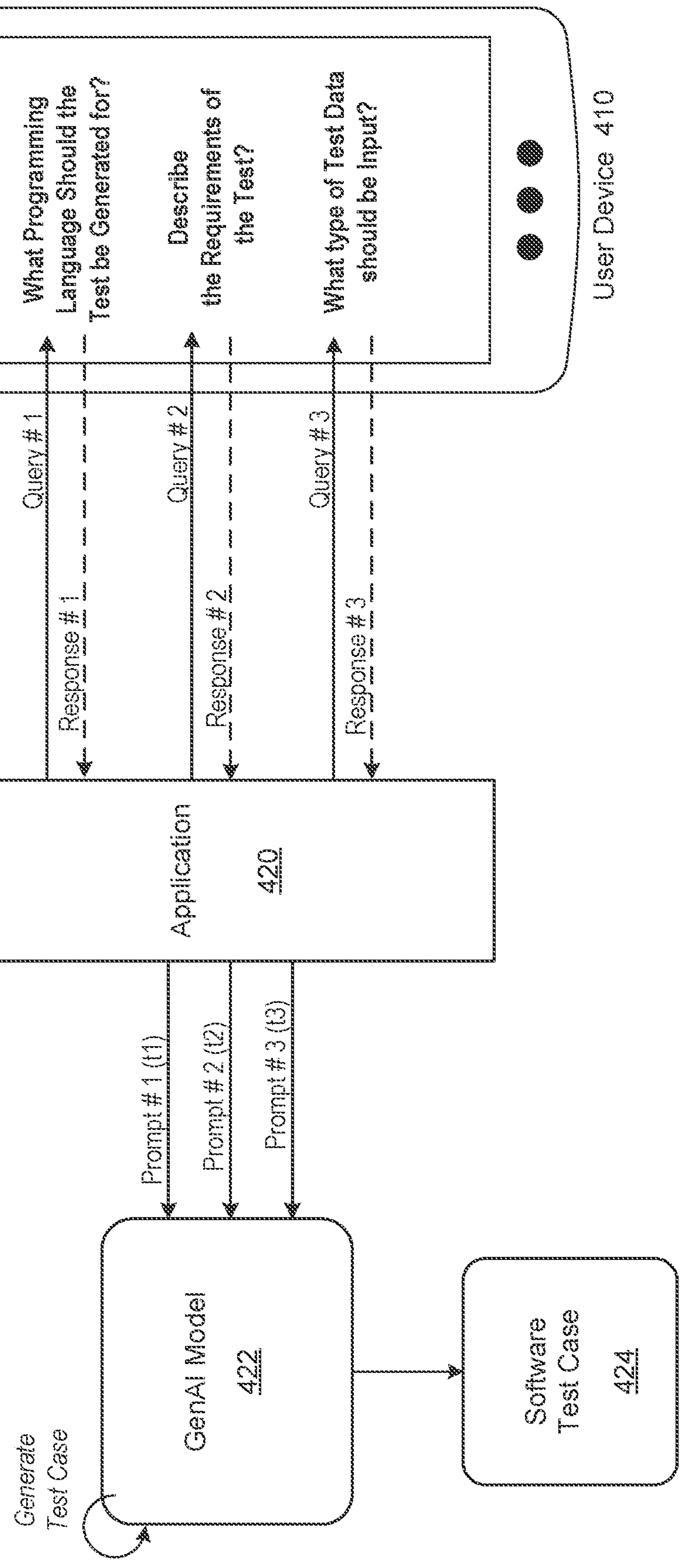
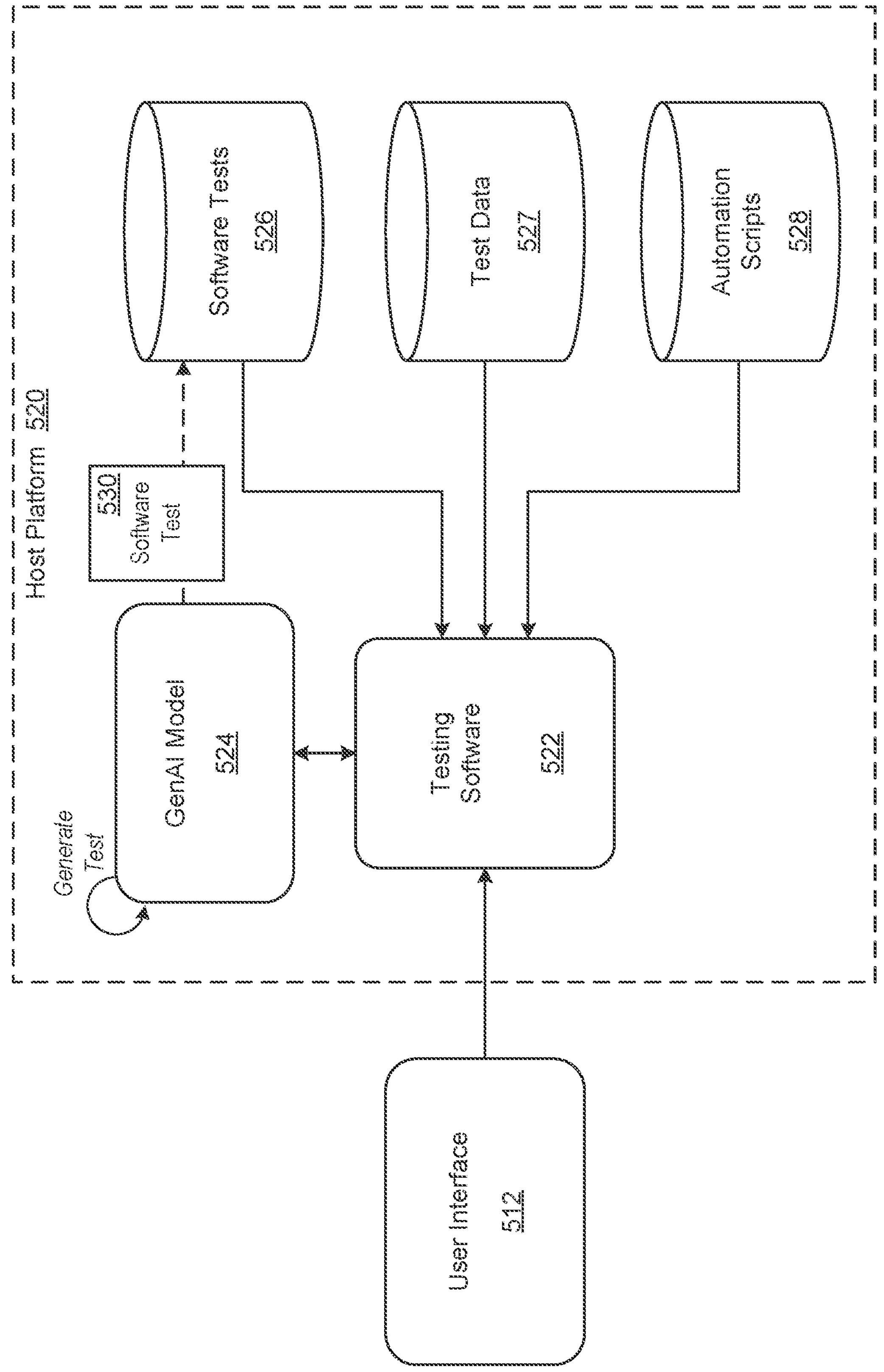

412
What Programming Language Should the Test be Generated for?
Describe the Requirements of the Test?
What type of Test Data should be Input?
User Device 410
Query # 1
Response # 1
Query # 2
Response # 2
Query # 3
Response # 3
Application
420
Prompt # 1 (t1)
Prompt # 2 (t2)
Prompt # 3 (t3)
GenAI Model
422
Generate Test Case
Software Test Case
424

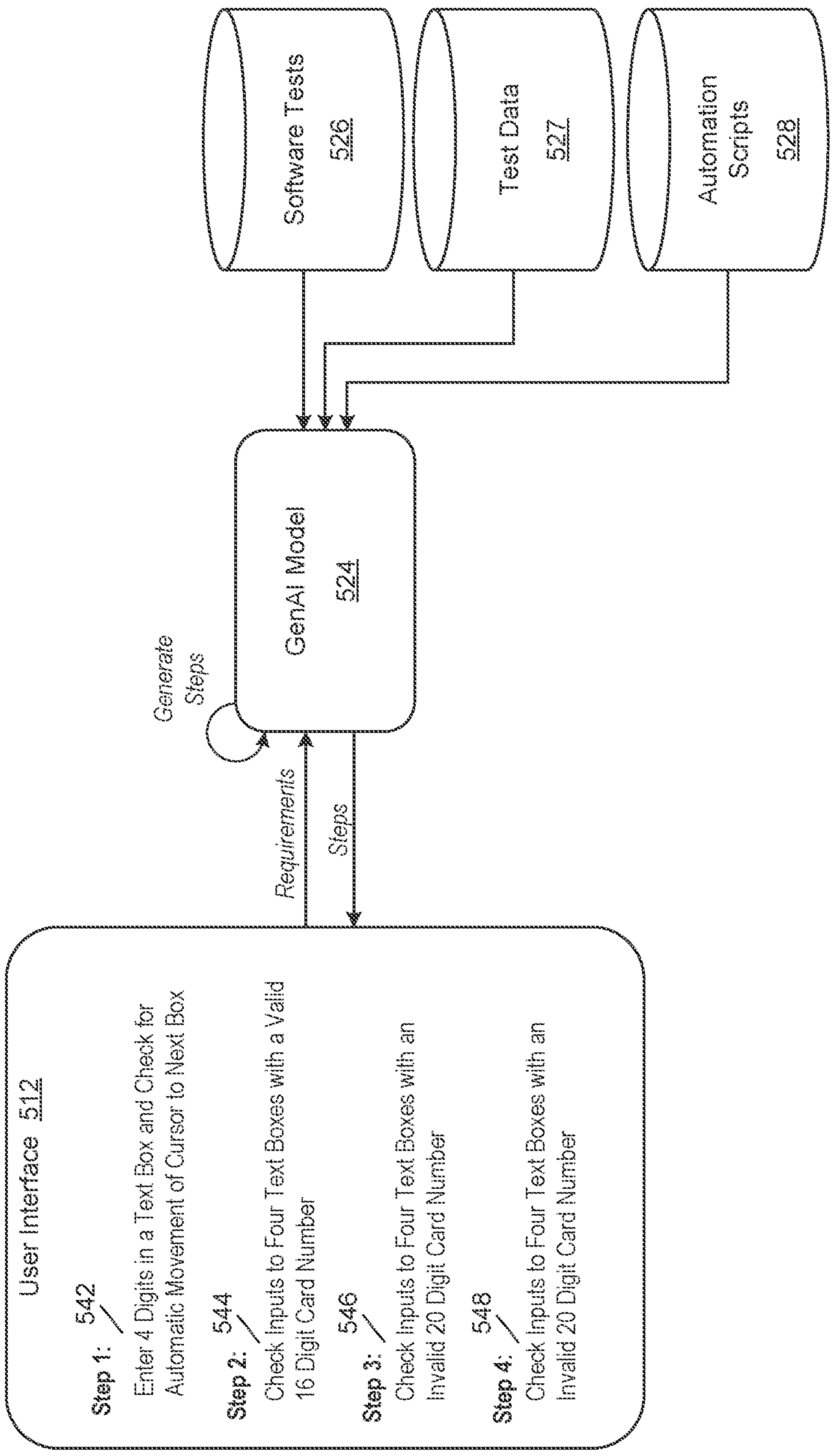
FIG. 5A

500


Host Platform 520
Software Tests 526
Test Data 527
Automation Scripts 528
530 Software Test
GenAI Model 524
Generate Test
Testing Software 522
User Interface 512

540

FIG 5B


Software Tests 526
Test Data 527
Automation Scripts 528
GenAI Model 524
Generate Steps
Requirements
Steps
User Interface 512
Step 1: 542 Enter 4 Digits in a Text Box and Check for Automatic Movement of Cursor to Next Box
Step 2: 544 Check Inputs to Four Text Boxes with a Valid 16 Digit Card Number
Step 3: 546 Check Inputs to Four Text Boxes with an Invalid 20 Digit Card Number
Step 4: 548 Check Inputs to Four Text Boxes with an Invalid 20 Digit Card Number

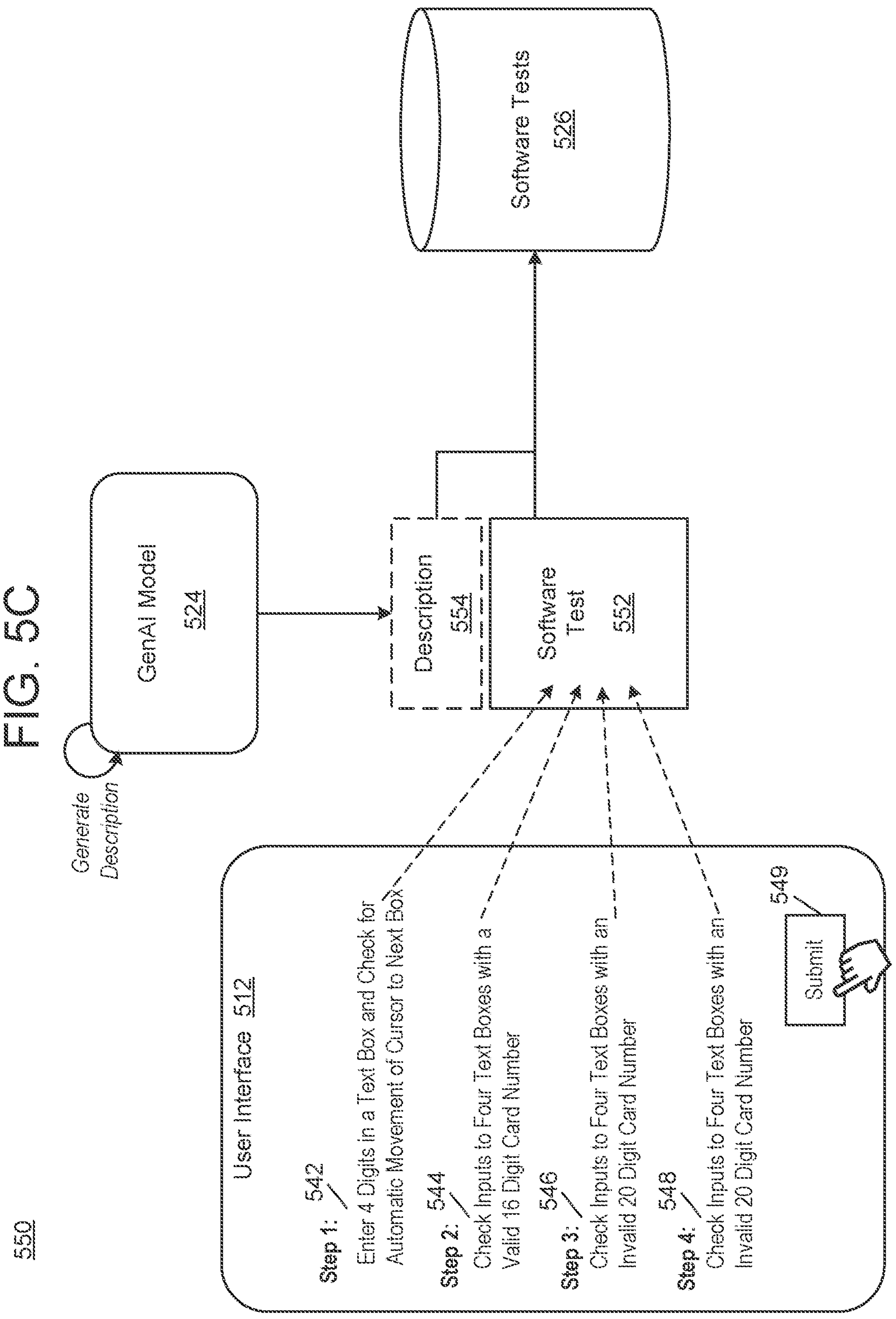

550
User Interface 512
Step 1: 542
Enter 4 Digits in a Text Box and Check for Automatic Movement of Cursor to Next Box
Step 2: 544
Check Inputs to Four Text Boxes with a Valid 16 Digit Card Number
Step 3: 546
Check Inputs to Four Text Boxes with an Invalid 20 Digit Card Number
Step 4: 548
Check Inputs to Four Text Boxes with an Invalid 20 Digit Card Number
549
Submit
Generate Description
GenAI Model 524
Description 554
Software Test 552
Software Tests 526

FIG. 5C

FIG. 5D

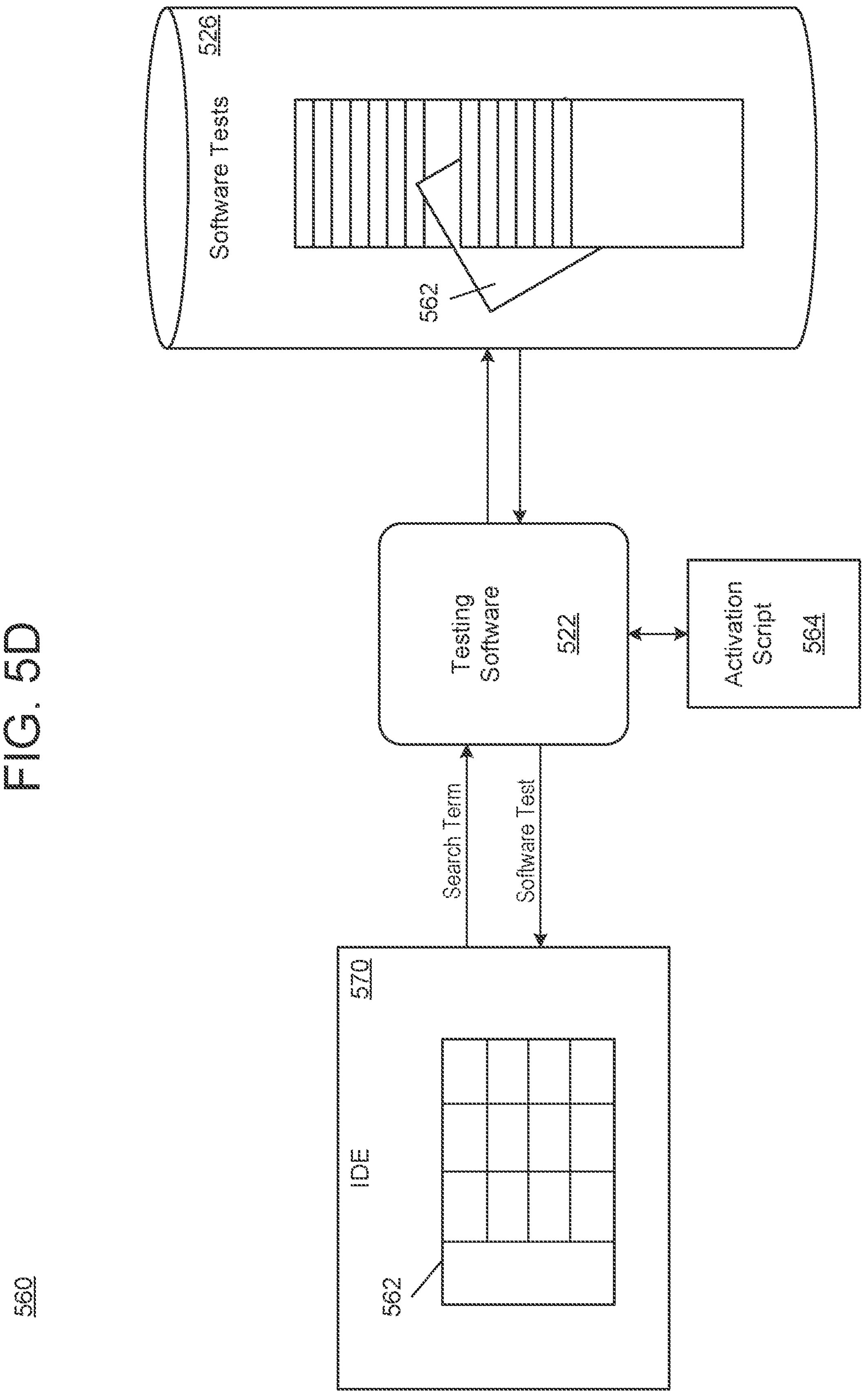

560
IDE
570
562
Search Term
Software Test
Testing Software
522
Activation Script
564
Software Tests
526
562

FIG. 6A

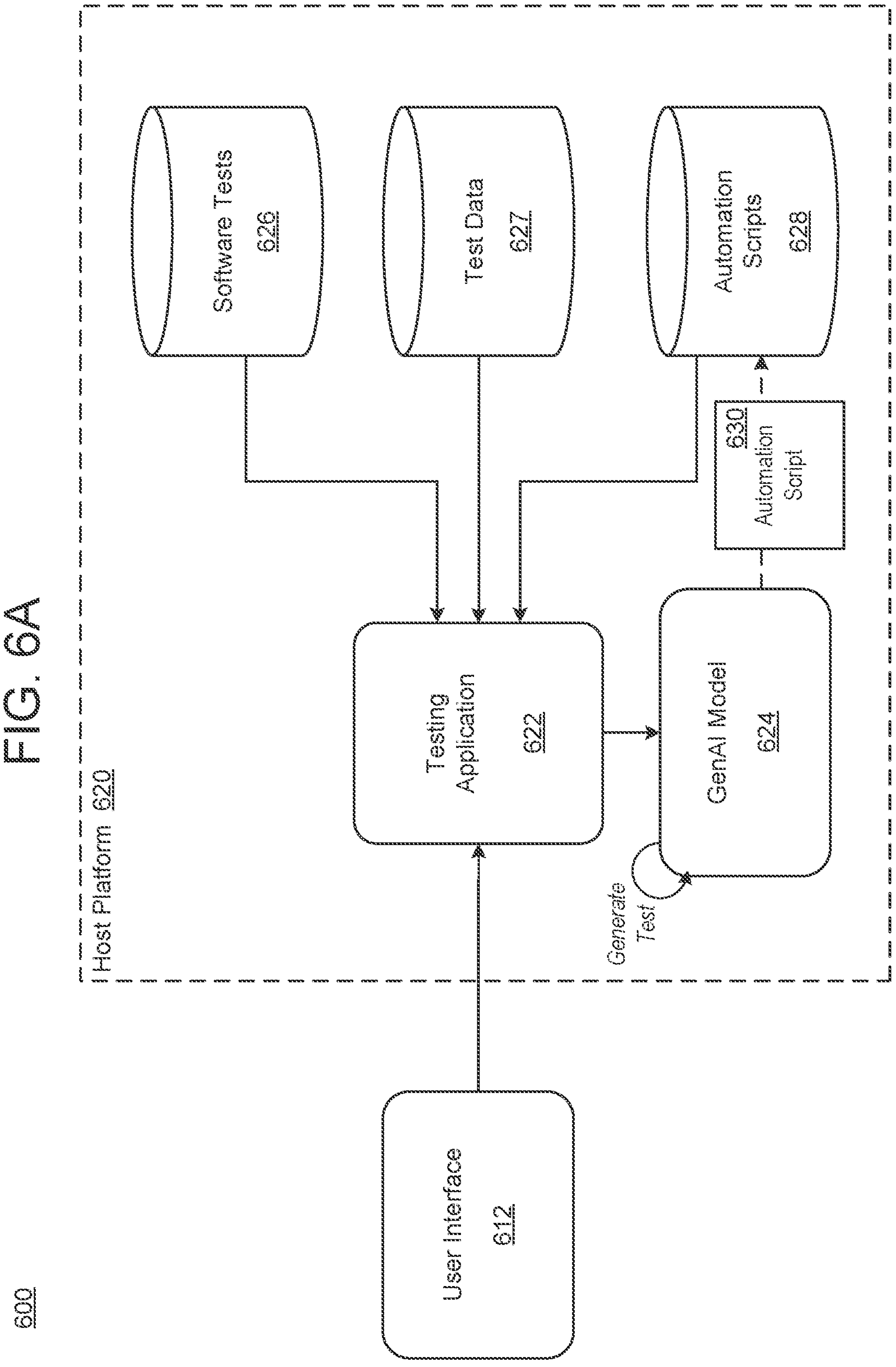
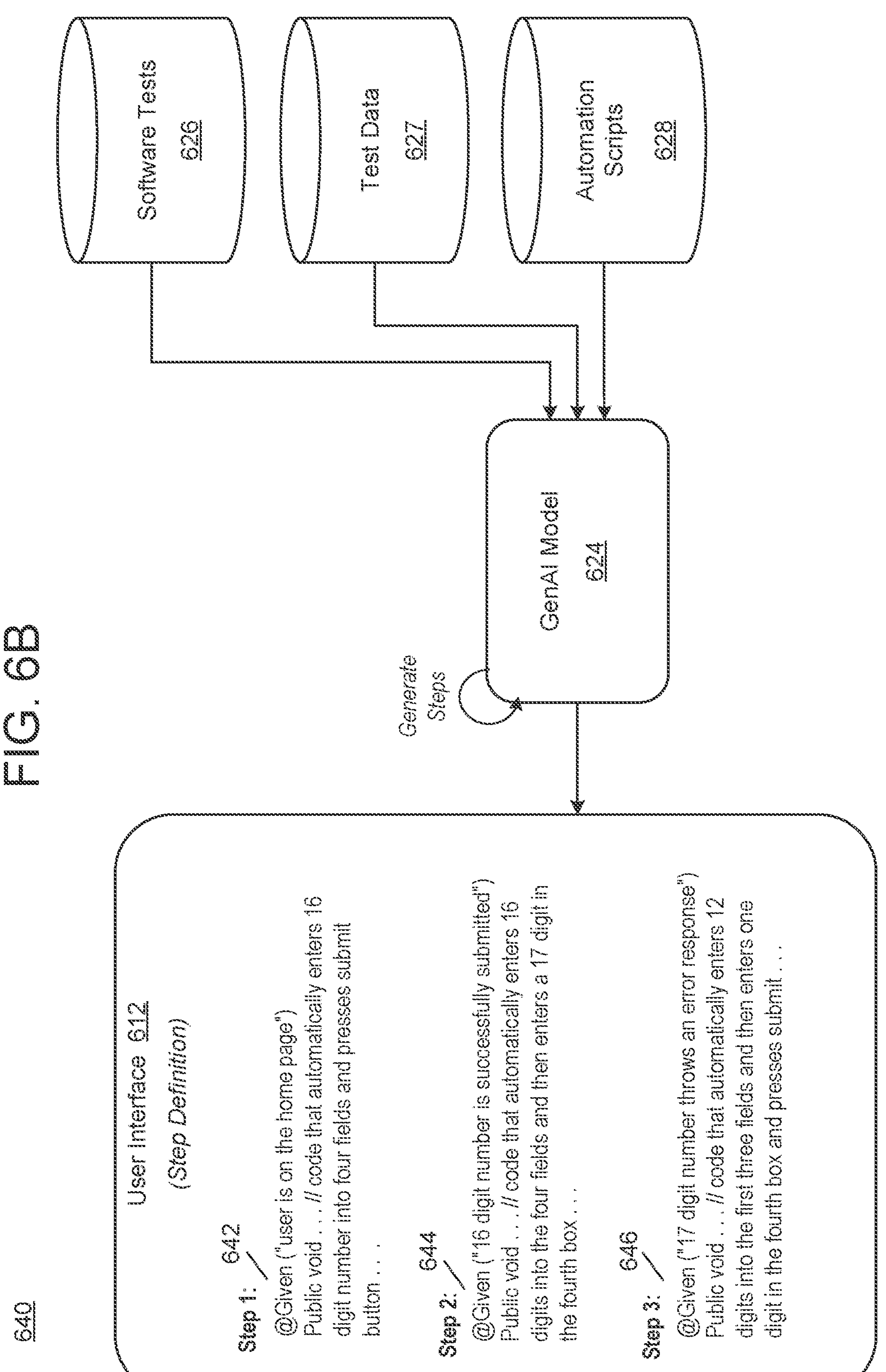

600
Host Platform 620
User Interface 612
Testing Application 622
GenAI Model 624
Generate Test
Software Tests 626
Test Data 627
Automation Scripts 628
630 Automation Script

FIG. 6B

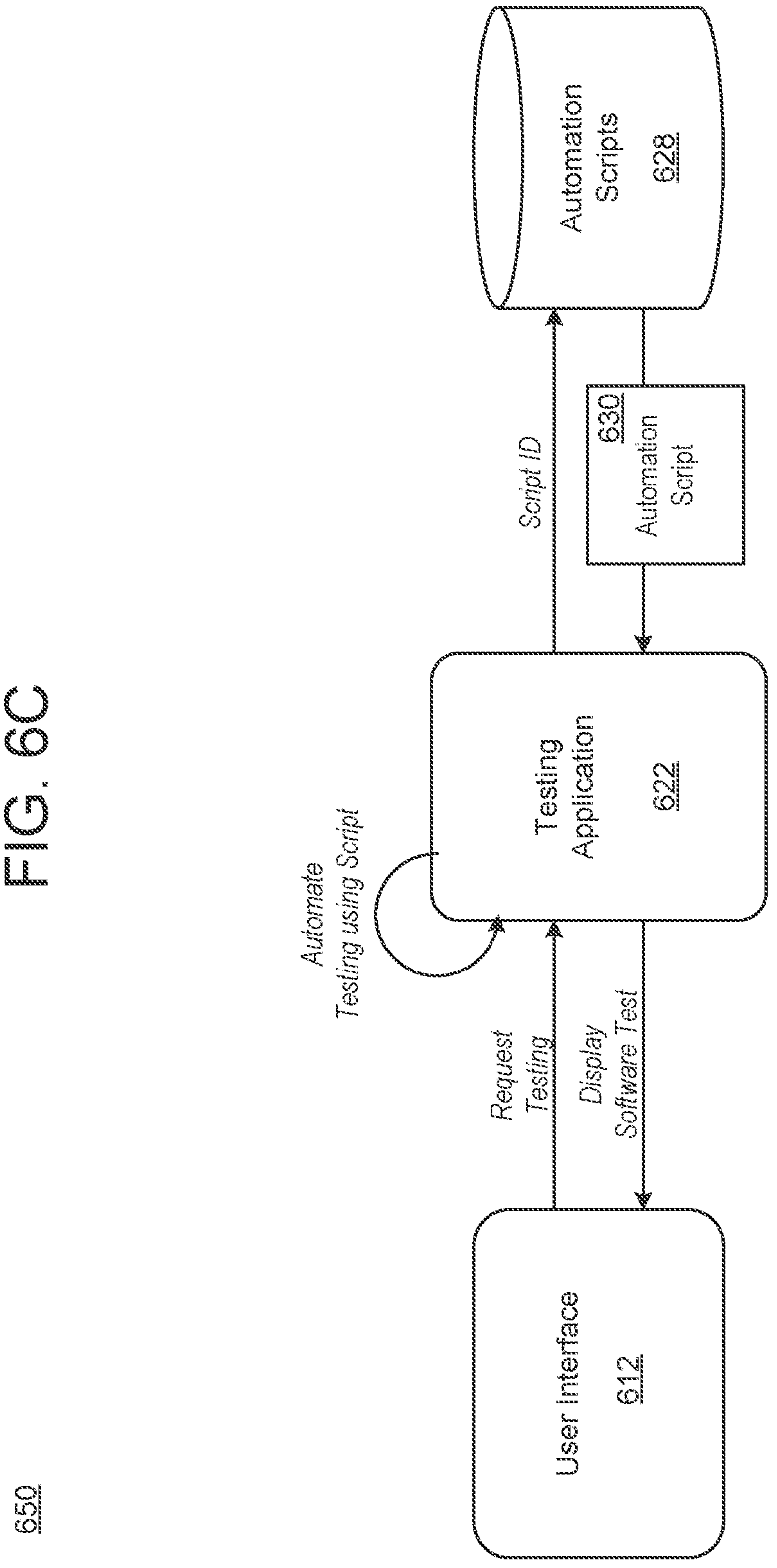


Step 1: @Given ("user is on the home page")
Public void . . . // code that automatically enters 16 digit number into four fields and presses submit button . . .

Step 2: @Given ("16 digit number is successfully submitted")
Public void . . . // code that automatically enters 16 digits into the four fields and then enters a 17 digit in the fourth box . . .

Step 3: @Given ("17 digit number throws an error response")
Public void . . . // code that automatically enters 12 digits into the first three fields and then enters one digit in the fourth box and presses submit . . .

FIG. 6C


650
User Interface
612
Request Testing
Display Software Test
Automate Testing using Script
Testing Application
622
Script ID
Automation Script
630
Automation Scripts
628

700

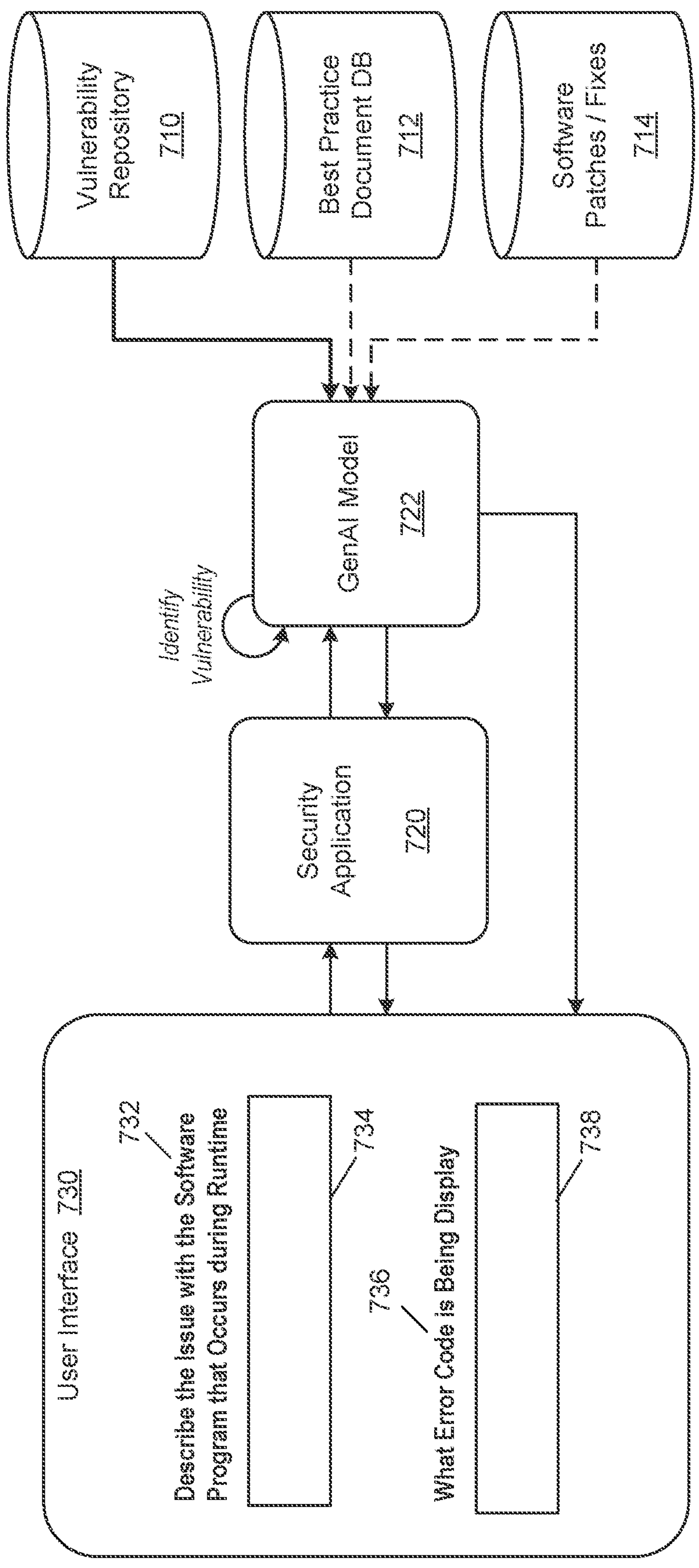
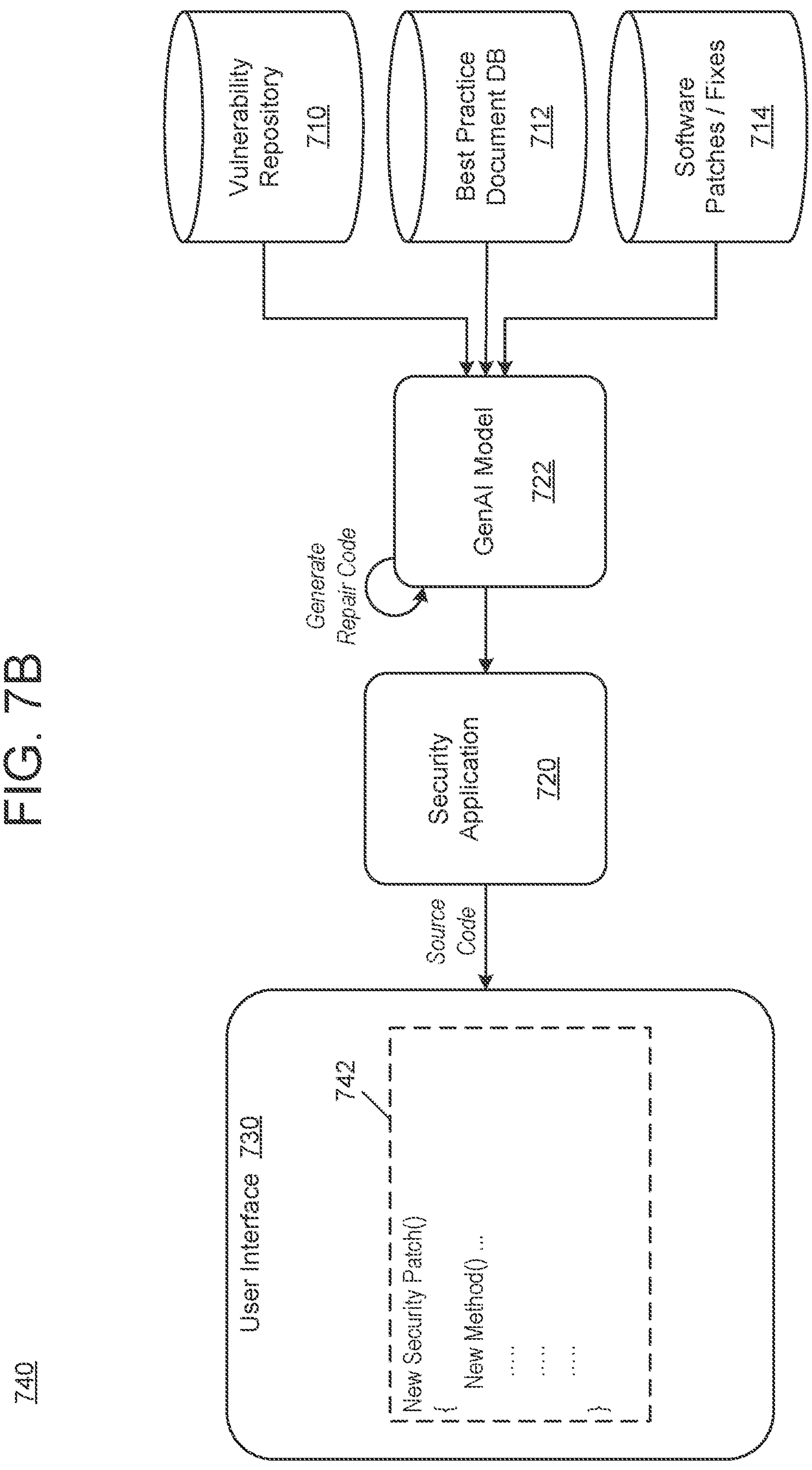

Vulnerability Repository 710
Best Practice Document DB 712
Software Patches / Fixes 714
GenAI Model 722
Identify Vulnerability
Security Application 720
User Interface 730
732
Describe the Issue with the Software Program that Occurs during Runtime
734
736
What Error Code is Being Display
738

FIG. 7A

FIG. 7B


Vulnerability Repository 710
Best Practice Document DB 712
Software Patches / Fixes 714
GenAI Model 722
Generate Repair Code
Security Application 720
Source Code
User Interface 730
742
New Security Patch()
{
New Method() ...
....
....
....
}
740

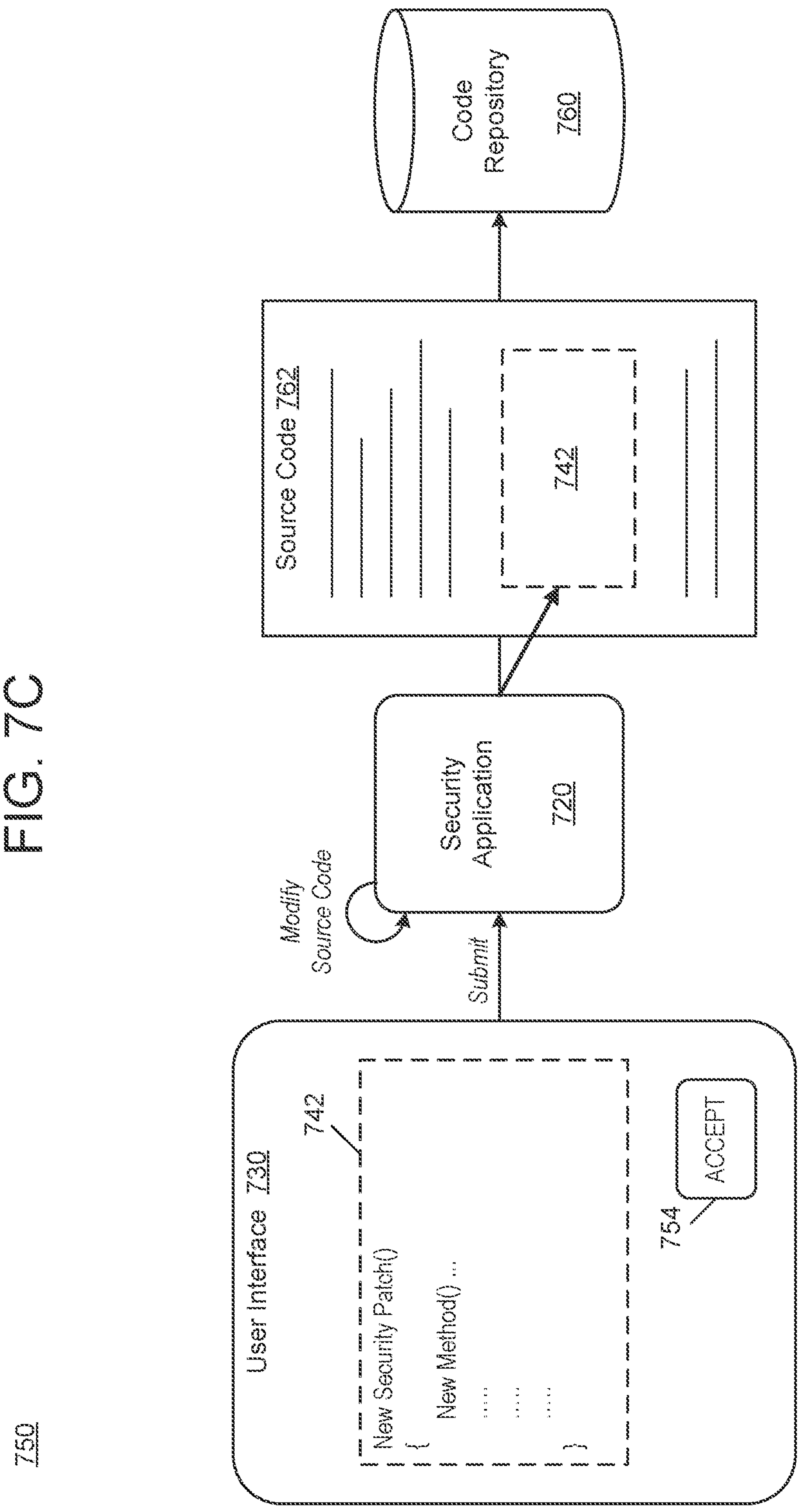

750
User Interface 730
742
New Security Patch()
{
New Method() ...
....
....
....
}
ACCEPT
754
Submit
Modify Source Code
Security Application
720
Source Code 762
742
Code Repository
760

FIG. 7C

FIG. 8A

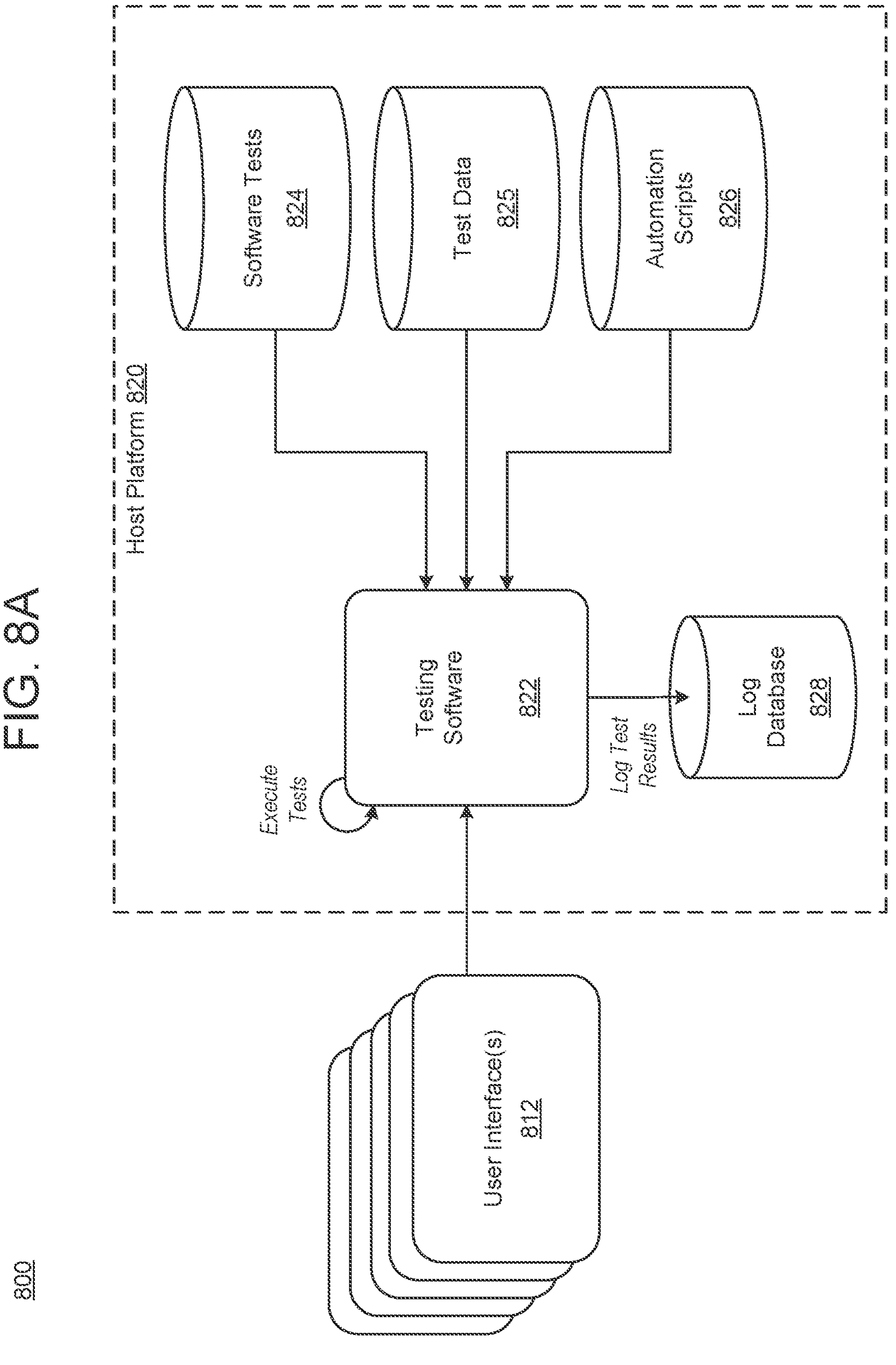

800
Host Platform 820
Software Tests 824
Test Data 825
Automation Scripts 826
Testing Software 822
Execute Tests
Log Test Results
Log Database 828
User Interface(s) 812

FIG. 8B

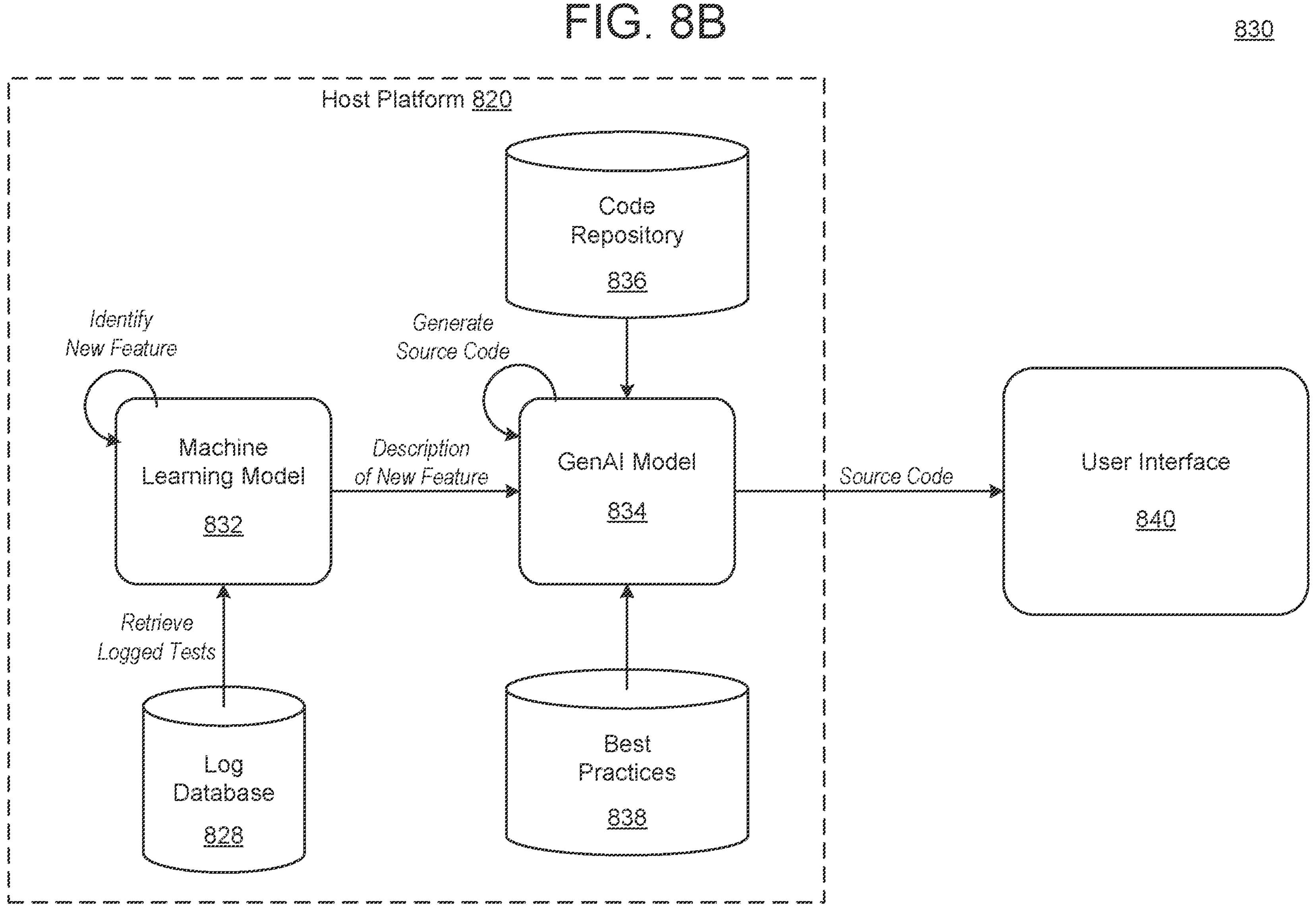
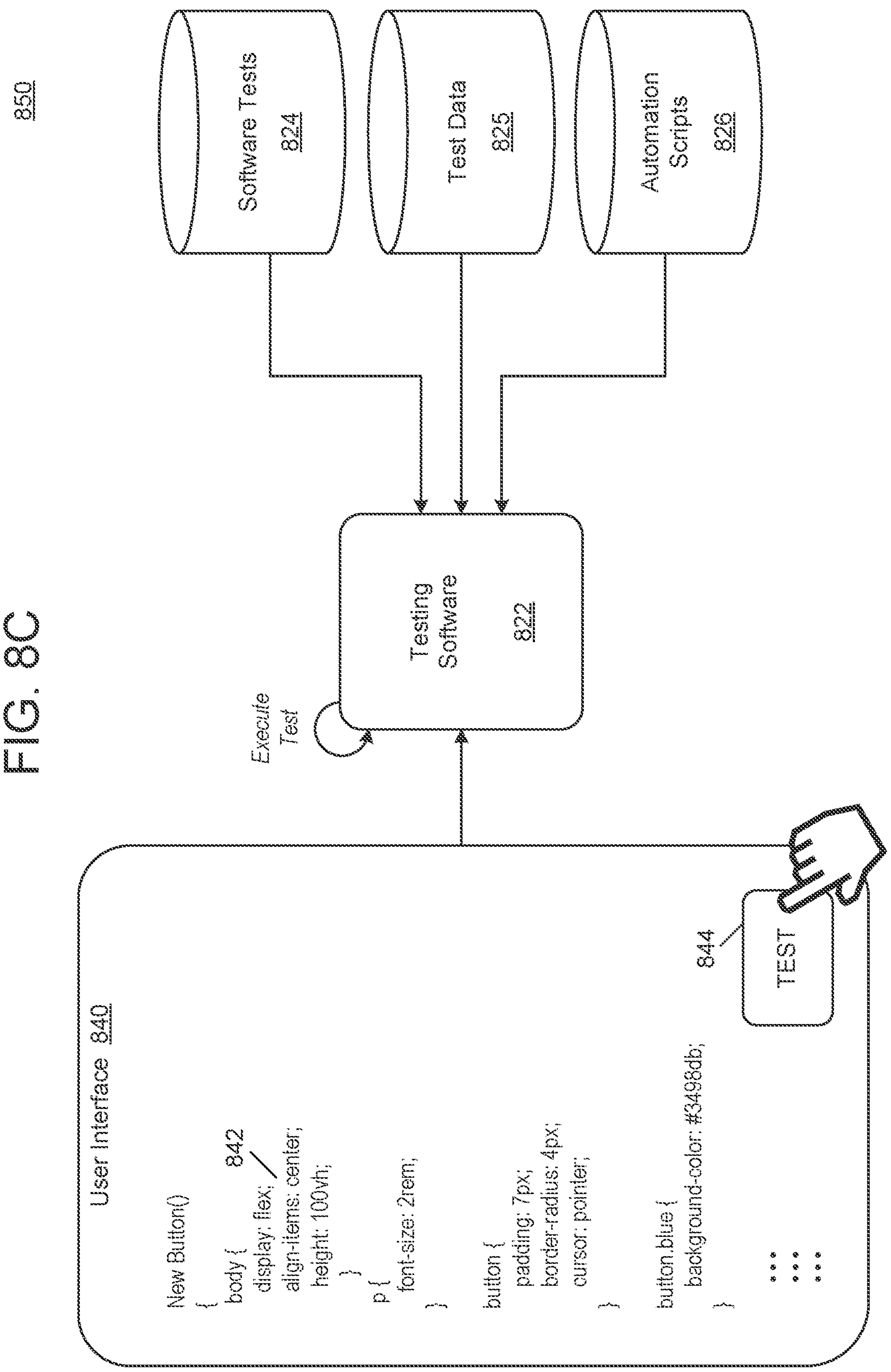

830
Host Platform 820
Code Repository 836
Identify New Feature
Generate Source Code
Machine Learning Model 832
Description of New Feature
GenAI Model 834
Source Code
User Interface 840
Retrieve Logged Tests
Log Database 828
Best Practices 838

FIG. 8C



```
New Button()
{
  body {
    display: flex;
    align-items: center;
    height: 100vh;
  }
  p {
    font-size: 2rem;
  }

  button {
    padding: 7px;
    border-radius: 4px;
    cursor: pointer;
  }

  button.blue {
    background-color: #3498db;
  }
  ...
```

FIG. 9A

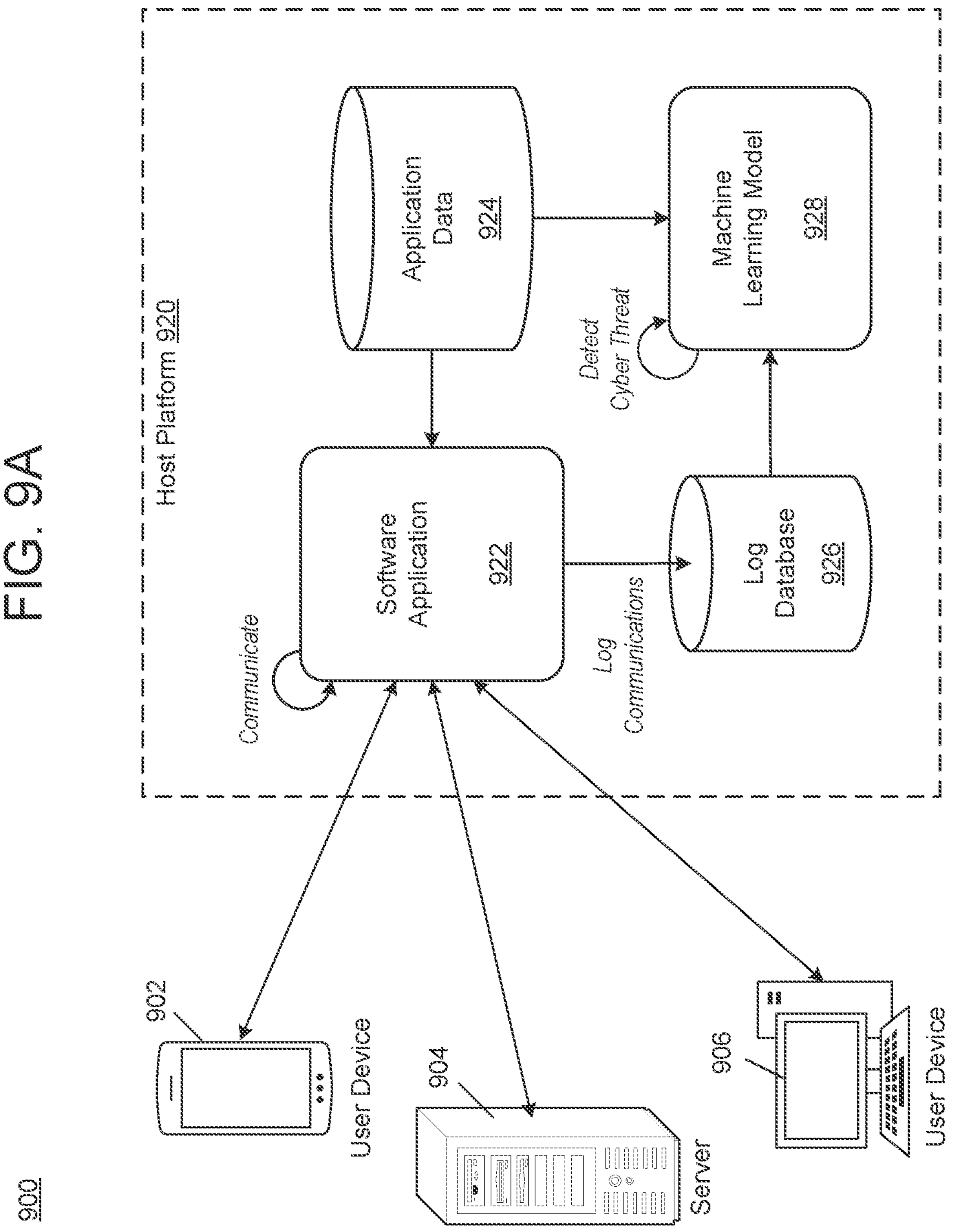

900
Host Platform 920
Application Data 924
Machine Learning Model 928
Software Application 922
Log Database 926
Communicate
Log Communications
Detect Cyber Threat
902
User Device
904
Server
906
User Device

FIG. 9B

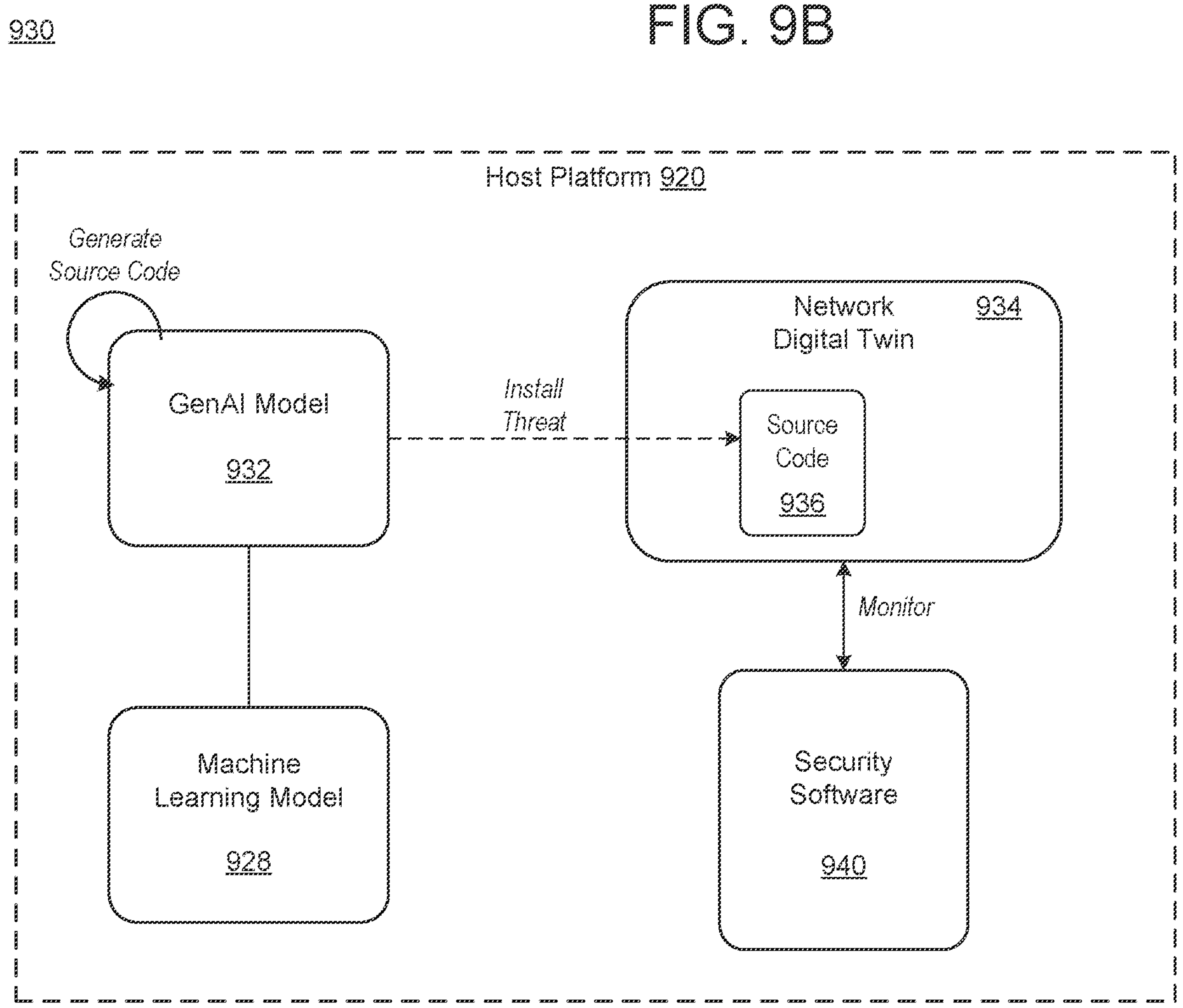

930
Host Platform 920
Generate Source Code
GenAI Model 932
Machine Learning Model 928
Install Threat
Network Digital Twin 934
Source Code 936
Monitor
Security Software 940

FIG. 10A

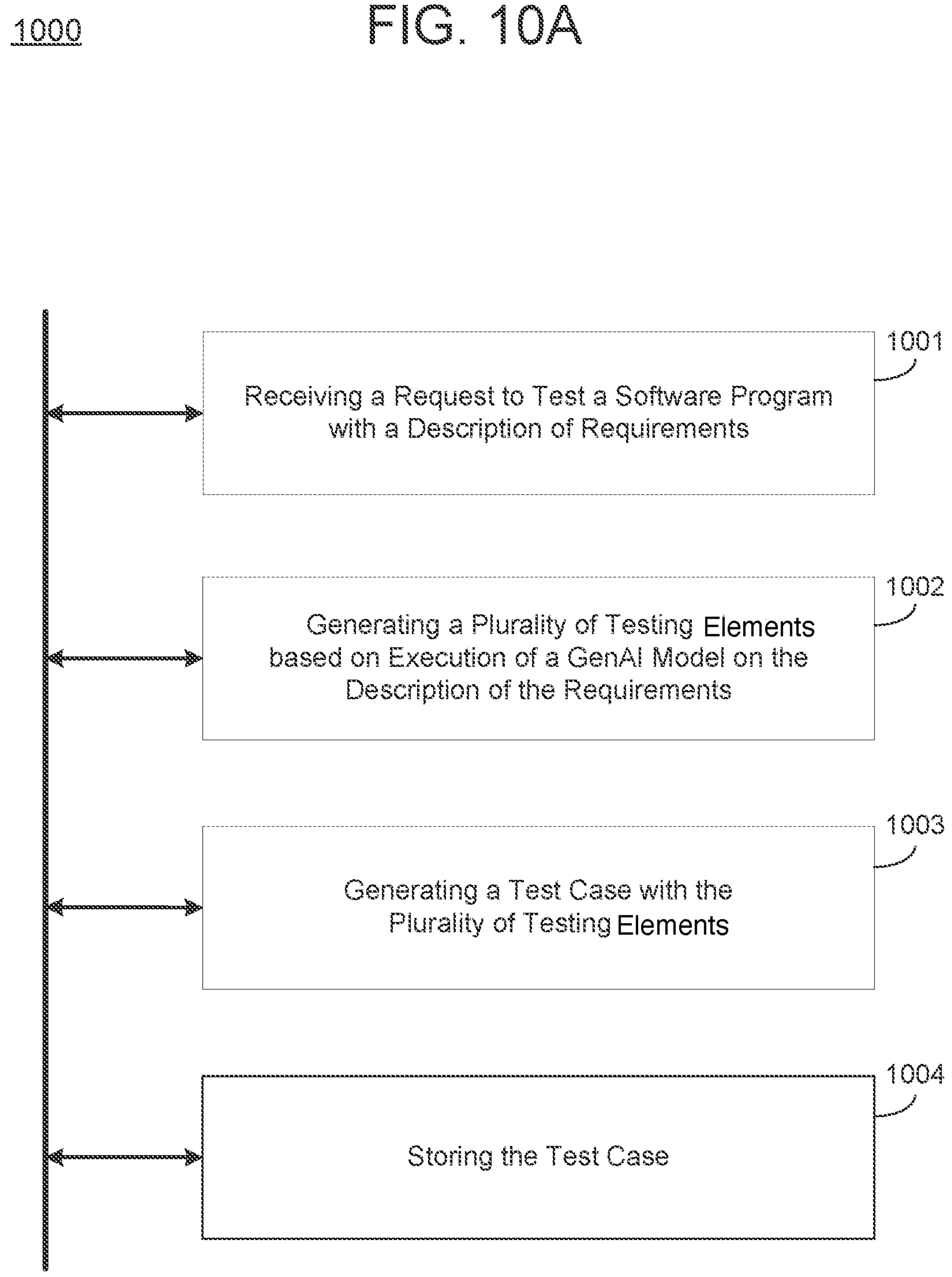

1000
1001
Receiving a Request to Test a Software Program with a Description of Requirements
1002
Generating a Plurality of Testing Elements based on Execution of a GenAI Model on the Description of the Requirements
1003
Generating a Test Case with the Plurality of Testing Elements
1004
Storing the Test Case

FIG. 10B

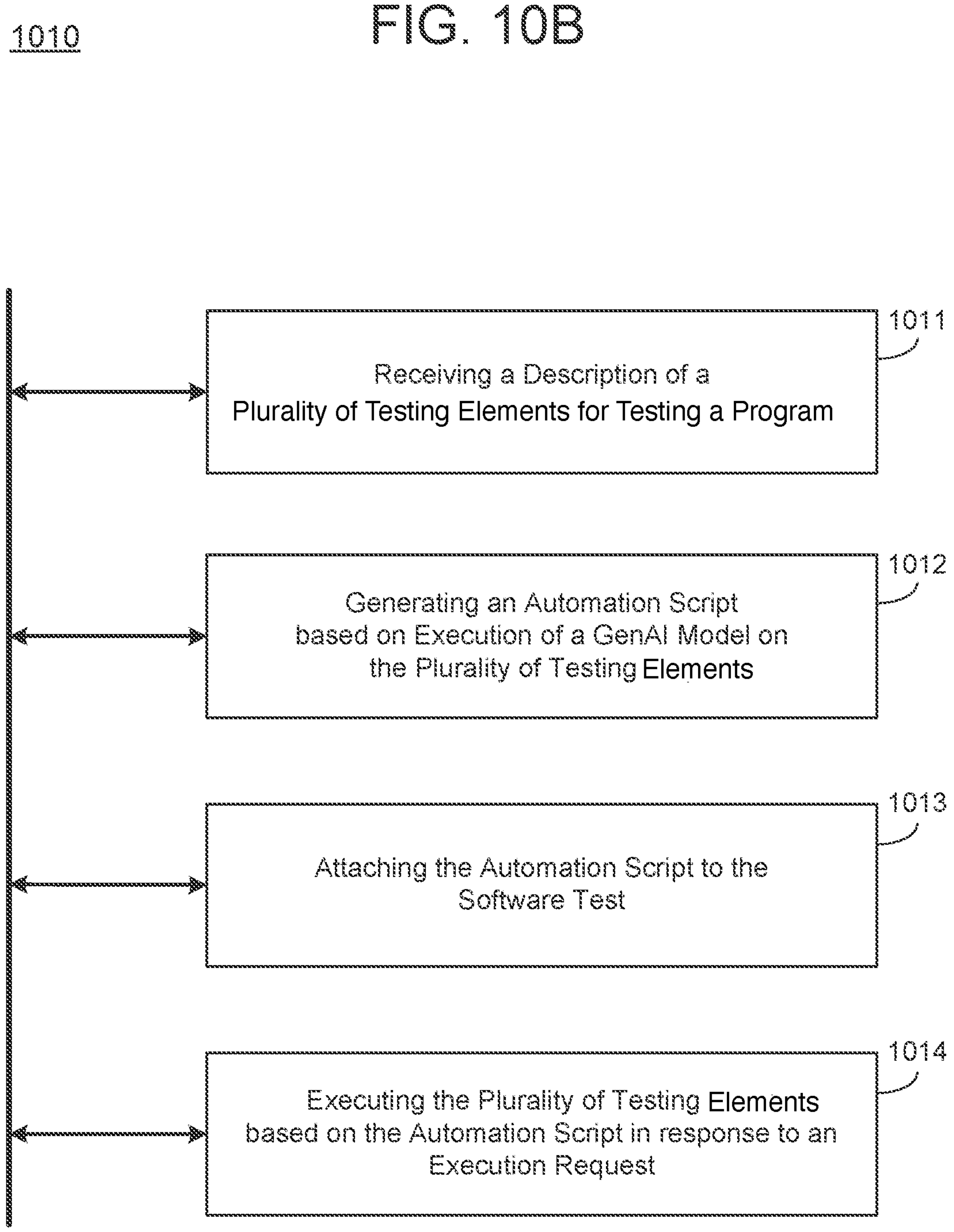

1010
1011
Receiving a Description of a Plurality of Testing Elements for Testing a Program
1012
Generating an Automation Script based on Execution of a GenAI Model on the Plurality of Testing Elements
1013
Attaching the Automation Script to the Software Test
1014
Executing the Plurality of Testing Elements based on the Automation Script in response to an Execution Request

FIG. 10C

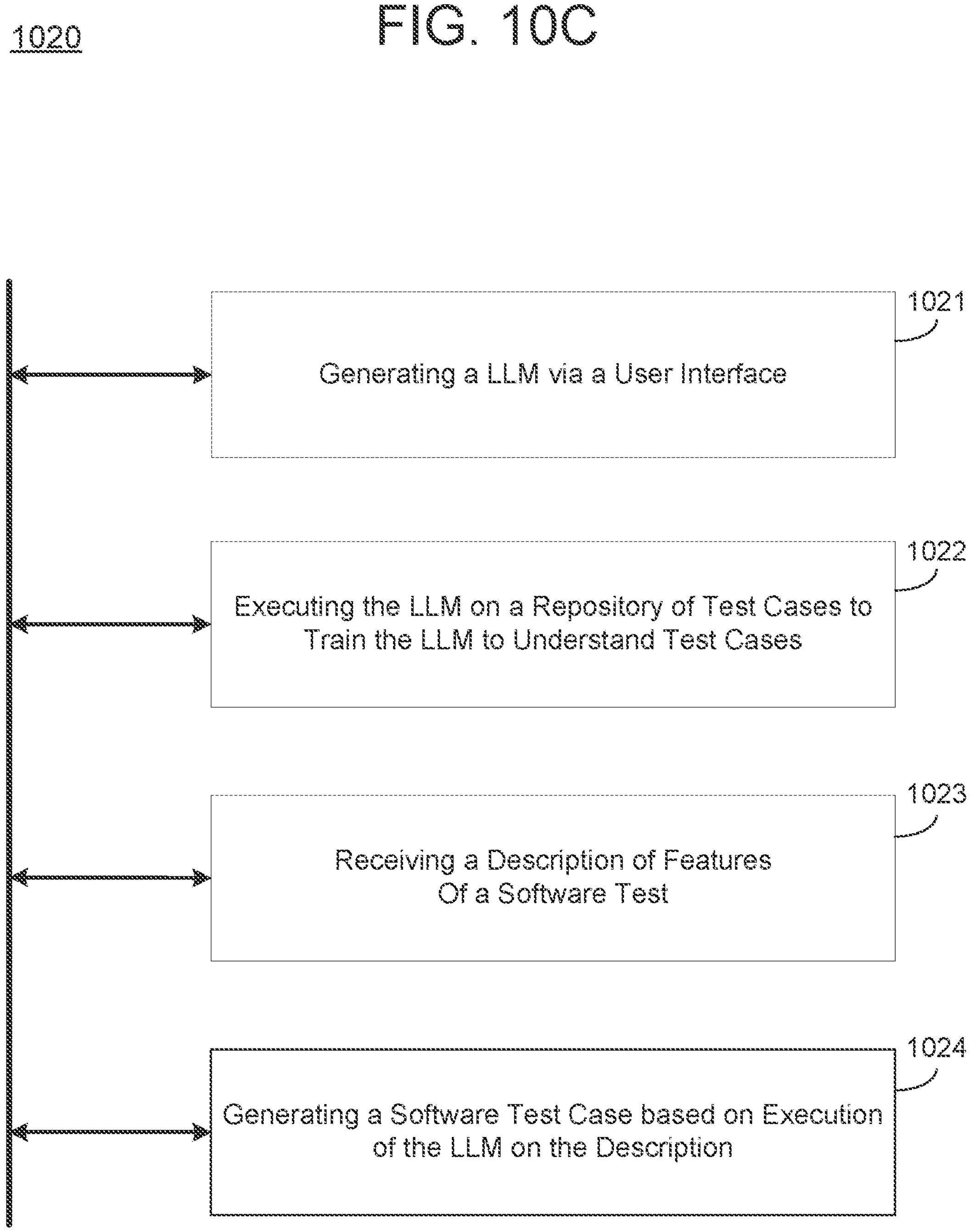

1020
1021
Generating a LLM via a User Interface
1022
Executing the LLM on a Repository of Test Cases to Train the LLM to Understand Test Cases
1023
Receiving a Description of Features Of a Software Test
1024
Generating a Software Test Case based on Execution of the LLM on the Description

FIG. 10D

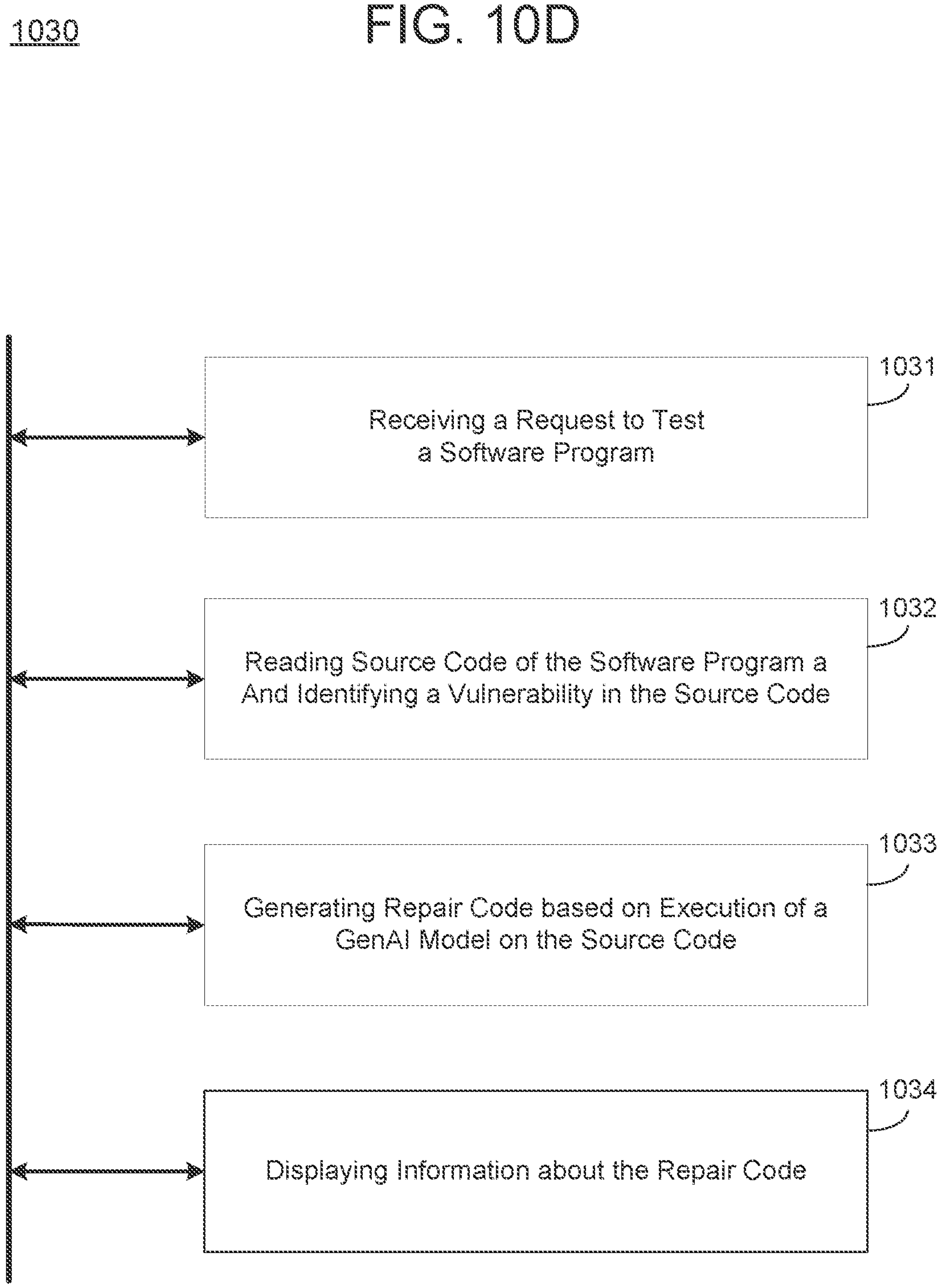

1030
1031
Receiving a Request to Test a Software Program
1032
Reading Source Code of the Software Program a And Identifying a Vulnerability in the Source Code
1033
Generating Repair Code based on Execution of a GenAI Model on the Source Code
1034
Displaying Information about the Repair Code

FIG. 10E

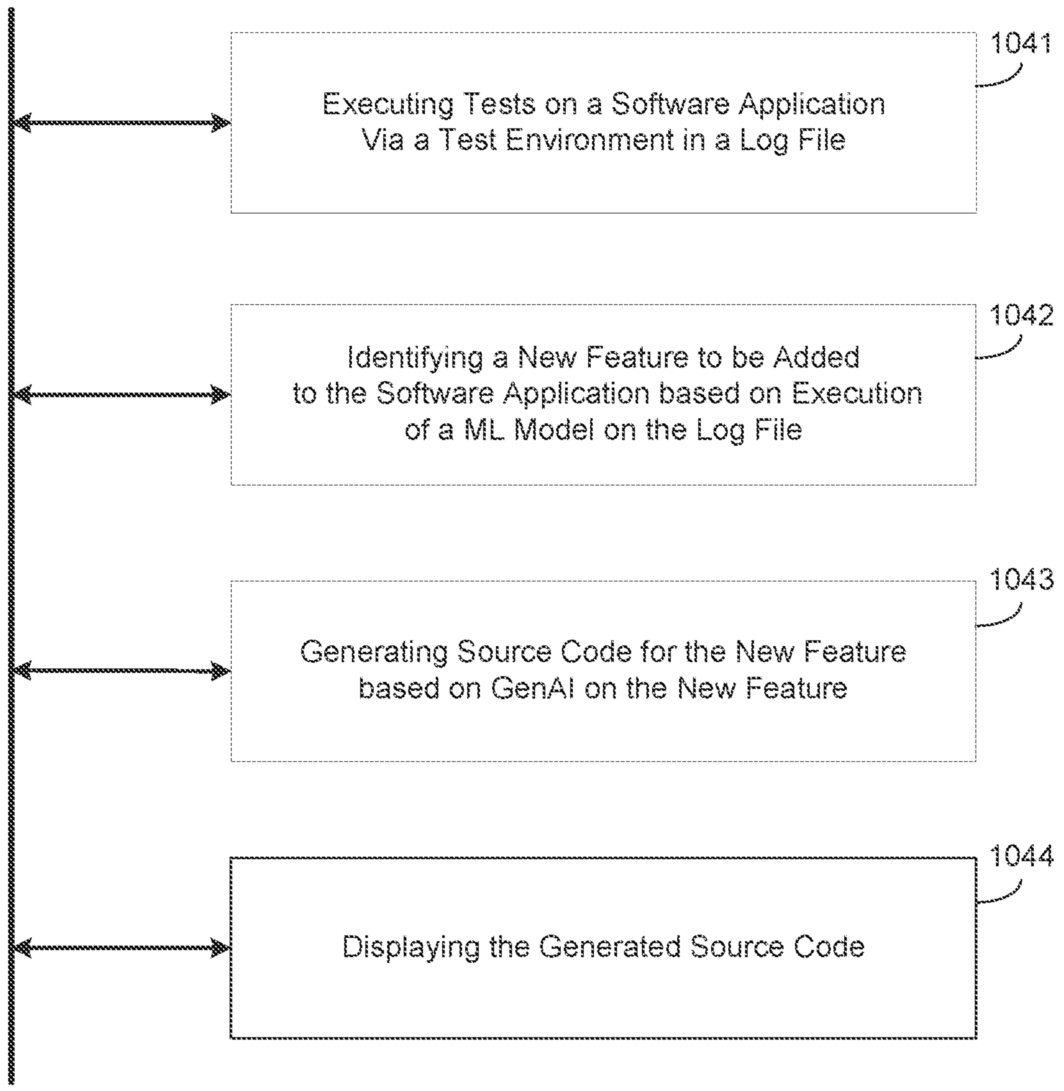

1040
1041
Executing Tests on a Software Application Via a Test Environment in a Log File
1042
Identifying a New Feature to be Added to the Software Application based on Execution of a ML Model on the Log File
1043
Generating Source Code for the New Feature based on GenAI on the New Feature
1044
Displaying the Generated Source Code

FIG. 10F

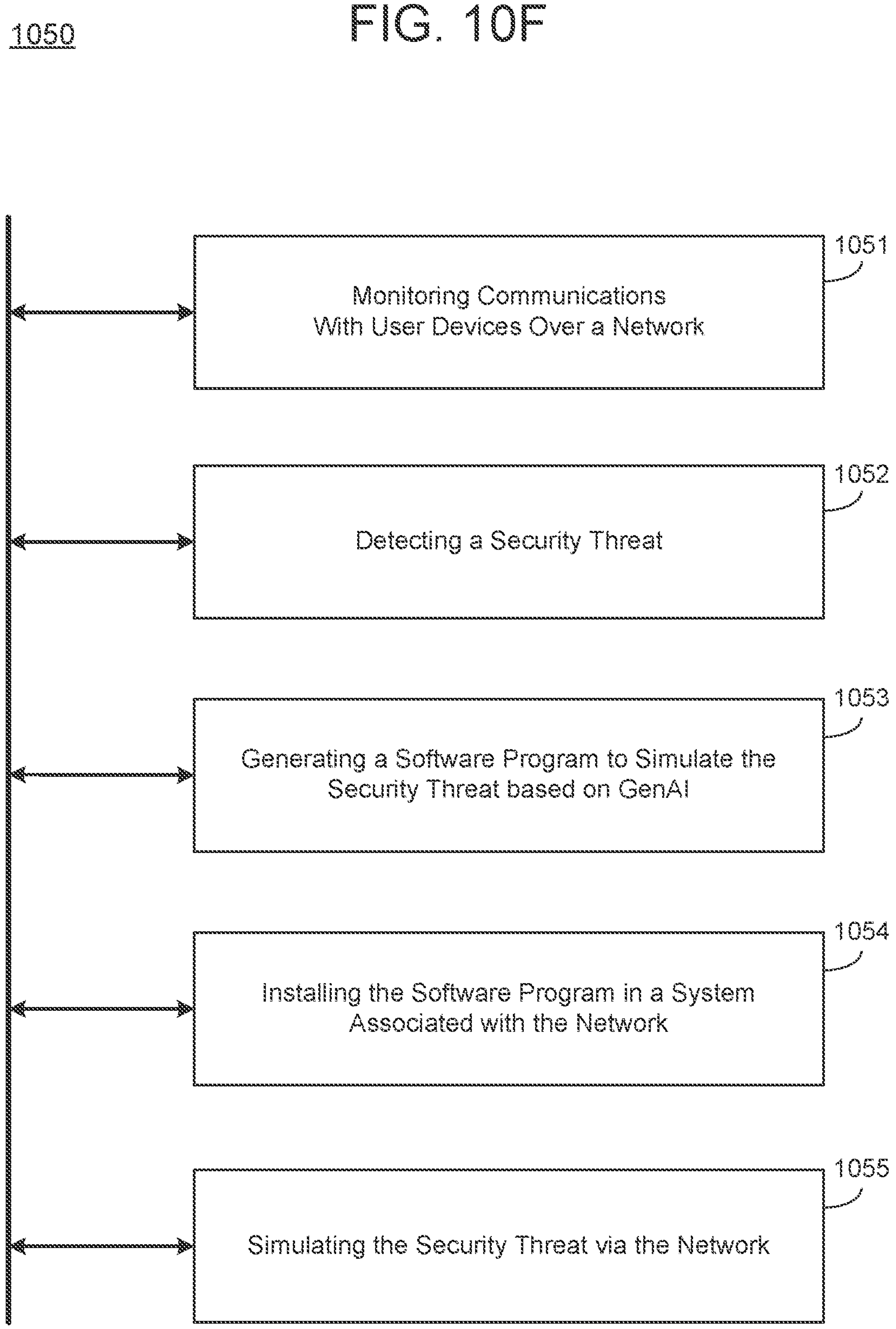
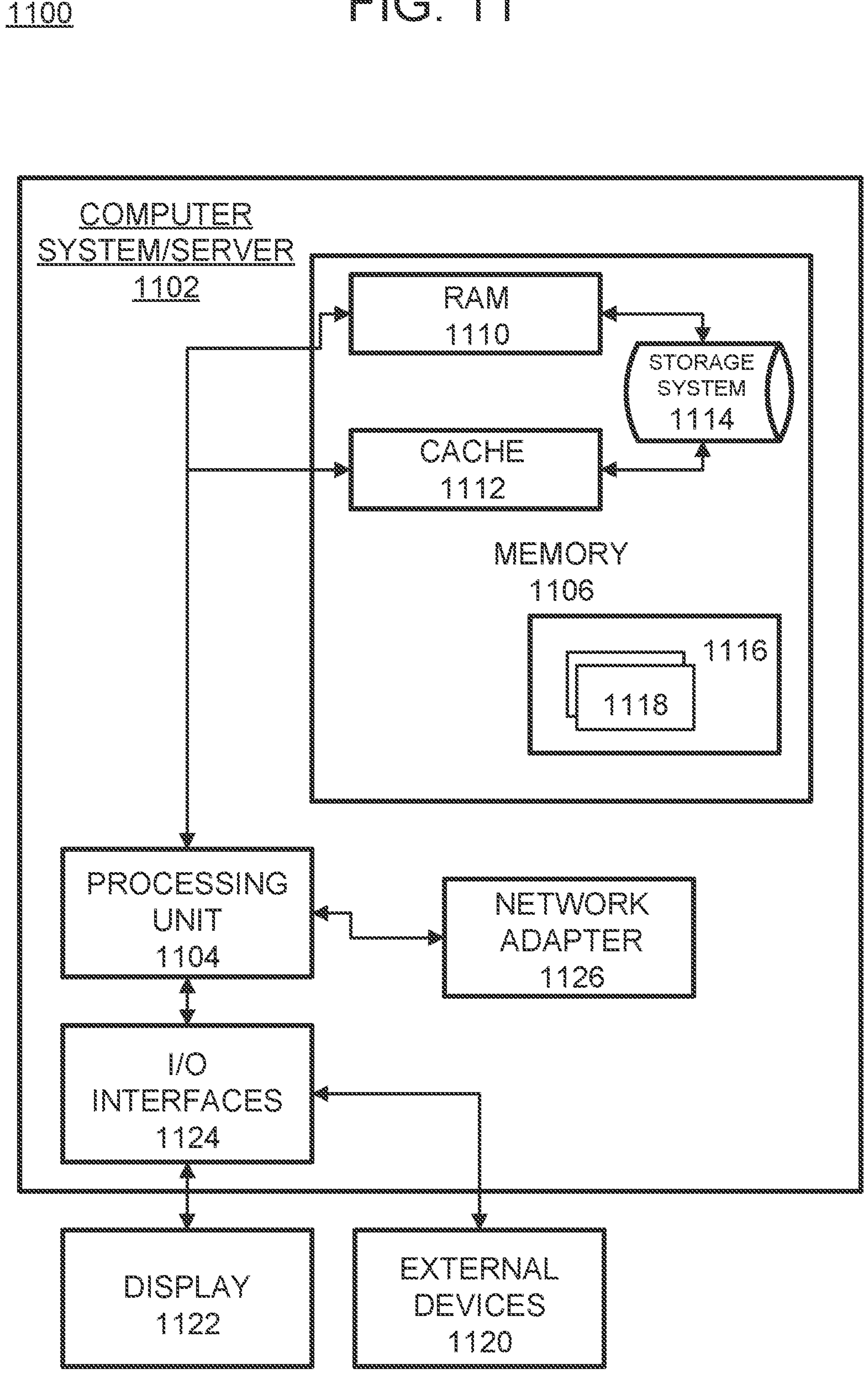

1050
1051
Monitoring Communications With User Devices Over a Network
1052
Detecting a Security Threat
1053
Generating a Software Program to Simulate the Security Threat based on GenAI
1054
Installing the Software Program in a System Associated with the Network
1055
Simulating the Security Threat via the Network

FIG. 11



1100
COMPUTER SYSTEM/SERVER 1102
RAM 1110
STORAGE SYSTEM 1114
CACHE 1112
MEMORY 1106
1116
1118
PROCESSING UNIT 1104
NETWORK ADAPTER 1126
I/O INTERFACES 1124
DISPLAY 1122
EXTERNAL DEVICES 1120

TEST CASE GENERATION USING GENERATING ARTIFICIAL INTELLIGENCE

BACKGROUND

[0001] Software testing is a process of checking whether an actual software program matches the expected requirements. During testing, a developer may use a testing tool, such as a software application, to evaluate one or more points of interest within the software program being tested. For example, the testing tool can identify gaps, missing requirements, etc., within the source code based on the execution of the software program in contrast to actual requirements, and the developer can submit fixes to repair or correct the defects and bugs. The testing may be repeated until the developer reaches a quality threshold that is acceptable. It has been shown that better-quality software tests shorten testing time. However, such tests require significant manual contribution of a developer(s).

SUMMARY

[0002] One example embodiment provides an apparatus that may include a memory, a network interface configured to receive a request to test a software program stored in the memory from a user device, the request comprising a description of requirements of the software program, and a processor coupled to the memory and the network interface, the processor configured to generate a plurality of testing elements based on execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases, generate a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model, and store the test case within the memory.

[0003] Another example embodiment provides a method that includes one or more of receiving a request to test a software program from a user device, the request comprising a description of requirements of the software program, generating a plurality of testing elements based on execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases, generating a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model, and storing the test case within a storage device.

[0004] A further example embodiment provides a computer-readable medium comprising instructions, that when read by a processor, cause the processor to perform one or more of receiving a request to test a software program from a user device, the request comprising a description of requirements of the software program, generating a plurality of testing elements based on execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases, generating a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model, and storing the test case within a storage device.

[0005] A further example embodiment provides an apparatus that may include a memory, and a processor coupled to the memory, the processor configured to receive a description of a plurality of testing elements for testing a software program and storing the software test within the memory, generate an automation script for automating execution of the software test based on execution of a generative artificial intelligence model (GenAI) model on the plurality of testing elements and a repository of automation scripts stored in the memory, attach the automation script to the software test within the memory, and in response to a request to execute the software test, execute the plurality of testing elements within the software test based on the attached automation script.

[0006] A further example embodiment provides a method that includes one or more of receiving a description of a plurality of testing elements for testing a software program and storing the software test within a storage device, generating an automation script for automating execution of the software test based on execution of a generative artificial intelligence model (GenAI) model on the plurality of testing elements and a repository of automation scripts, attaching the automation script to the software test within the storage device, and in response to a request to execute the software test, executing the plurality of testing elements within the software test based on the attached automation script.

[0007] A further example embodiment provides a computer-readable medium comprising instructions, that when read by a processor, cause the processor to perform one or more of receiving a description of a plurality of testing elements for testing a software program and storing the software test within a storage device, generating an automation script for automating execution of the software test based on execution of a generative artificial intelligence model (GenAI) model on the plurality of testing elements and a repository of automation scripts, attaching the automation script to the software test within the storage device, and in response to a request to execute the software test, executing the plurality of testing elements within the software test based on the attached automation script.

[0008] A further example embodiment provides an apparatus that may include a memory, a display, and a processor coupled to the memory and the display, the processor configured to: generate a large language model via a user interface and store the large language model in the memory, execute the large language model on a repository of software test cases and requirements of the software test cases to train the large language model to understand connections between test case components and test case requirements and store the trained large language model in the memory, receive a description of features of a software program to be tested, and in response to receiving the description of the features, generate a software test case based on execution of the large language model on the received descriptions, and display on the display the software test case via a user interface.

[0009] A further example embodiment provides a method that includes one or more of generating a large language model via a user interface, executing the large language model on a repository of software test cases and requirements of the software test cases to train the large language model to understand connections between test case components and test case requirements, receiving a description of features of a software program to be tested; and in response to receiving the description of the features, generating a software test case based on execution of the large language model on the received descriptions, and displaying the software test case via the user interface.

[0010] A further example embodiment provides a computer-readable medium comprising instructions, that when read by a processor, cause the processor to perform one or more of generating a large language model via a user interface, executing the large language model on a repository of software test cases and requirements of the software test cases to train the large language model to understand connections between test case components and test case requirements, receiving a description of features of a software program to be tested; and in response to receiving the description of the features, generating a software test case based on execution of the large language model on the received descriptions, and displaying the software test case via the user interface.

[0011] A further example embodiment provides an apparatus that may include a memory configured to store a log file, a display, and a processor coupled to the memory and the display, the processor configured to execute tests on a software application stored in the memory and running on the apparatus via a test environment of a test platform and log results of the tests in the log file, identify a new feature to be added to the software application based on execution of a machine learning model on logged results of the tests stored in the log file, generate source code for the new feature to be added to the software application based on execution of a generative artificial intelligence (GenAI) model on the new feature and a repository of source code stored in the memory, and display the generated source code on the display via a user interface of the software application.

[0012] A further example embodiment provides a method that includes one or more of executing tests on a software application via a test environment of a test platform and logging results of the tests in a log file, identifying a new feature to be added to the software application based on execution of a machine learning model on logged results of the tests stored in the log file, generating source code for the new feature to be added to the software application based on execution of a generative artificial intelligence (GenAI) model on the new feature and a repository of source code, and displaying the generated source code via a user interface of the software application.

[0013] A further example embodiment provides a computer-readable medium comprising instructions, that when read by a processor, cause the processor to perform one or more of executing tests on a software application via a test environment of a test platform and logging results of the tests in a log file, identifying a new feature to be added to the software application based on execution of a machine learning model on logged results of the tests stored in the log file, generating source code for the new feature to be added to the software application based on execution of a generative artificial intelligence (GenAI) model on the new feature and a repository of source code, and displaying the generated source code via a user interface of the software application.

[0014] A further example embodiment provides an apparatus that may include a memory comprising a repository of source code, and a processor configured to monitor communications that occur with user devices over a shared computer network, detect a security threat from the monitored communications, generate a software program to simulate the security threat over the shared computer network based on execution of a generative artificial intelligence (GenAI) model on the repository of source code and a description of the security threat, install the source code for simulating the security threat on a system associated with the computer network, and execute the source code for simulating the security threat via the system.

[0015] A further example embodiment provides a method that includes one or more of monitoring communications that occur with user devices over a shared computer network, detecting a security threat from the monitored communications, generating a software program to simulate the security threat over the shared computer network based on execution of a generative artificial intelligence (GenAI) model on a description of the security threat and a repository of source code, installing the source code for simulating the security threat on a system associated with the computer network, and executing the source code for simulating the security threat via the system.

[0016] A further example embodiment provides a computer-readable medium comprising instructions, that when read by a processor, cause the processor to perform one or more of monitoring communications that occur with user devices over a shared computer network, detecting a security threat from the monitored communications, generating a software program to simulate the security threat over the shared computer network based on execution of a generative artificial intelligence (GenAI) model on a description of the security threat and a repository of source code, installing the source code for simulating the security threat on a system associated with the computer network, and executing the source code for simulating the security threat via the system.

[0017] A further example embodiment provides an apparatus that may include a memory, a display, and a processor coupled to the memory and the display, the processor configured to receive, via a user interface, a request to test a software program that is stored in the memory, read source code of the software program from the memory and identify a vulnerability in the source code based on the reading, generate repair code for fixing the identified vulnerability based on execution of a generative artificial intelligence (GenAI) model on the source code and a repository of repair code stored in the memory which is used to repair previous vulnerabilities, and display on the display information about the repair code via the user interface.

[0018] A further example embodiment provides a method that includes one or more of receiving, via a user interface, a request to test a software program, reading source code of the software program and identifying a vulnerability in the source code based on the reading, generating repair code for fixing the identified vulnerability based on execution of a generative artificial intelligence (GenAI) model on the source code and a repository of repair code used to repair previous vulnerabilities, and displaying information about the repair code via the user interface.

[0019] A further example embodiment provides a computer-readable medium comprising instructions, that when read by a processor, cause the processor to perform one or more of receiving, via a user interface, a request to test a software program, reading source code of the software program and identifying a vulnerability in the source code based on the reading, generating repair code for fixing the identified vulnerability based on execution of a generative artificial intelligence (GenAI) model on the source code and a repository of repair code used to repair previous vulnerabilities, and displaying information about the repair code via the user interface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1**A is a diagram illustrating a generative artificial intelligence (GenAI) computing environment for generating test cases according to example embodiments.

[0021] FIG. **1**B is a diagram illustrating an example of a software test case generated by GenAI according to example embodiments.

[0022] FIG. **2** is a diagram illustrating a process of executing a predictive model on input content according to example embodiments.

[0023] FIGS. **3**A-**3**C are diagrams illustrating processes for training an artificial intelligence (AI) model according to example embodiments.

[0024] FIG. **4** is a diagram illustrating a process of prompting a GenAI model to generate an architecture diagram according to example embodiments.

[0025] FIGS. **5**A-**5**D are diagrams illustrating a process of generating a software test according to example embodiments.

[0026] FIGS. **6**A-**6**C are diagrams illustrating a process of generating an automation test script according to example embodiments.

[0027] FIGS. **7**A-**7**C are diagrams illustrating a process of identifying and testing a software vulnerability according to example embodiments.

[0028] FIGS. **8**A-**8**C are diagrams illustrating a process of generating new features for a software application based on software testing according to example embodiments.

[0029] FIGS. **9**A-**9**B are diagrams illustrating a process of detecting a security threat and simulating the security threat on a computer network according to example embodiments.

[0030] FIG. **10**A is a diagram illustrating a method of generating a software test case using GenAI according to example embodiments.

[0031] FIG. **10**B is a diagram illustrating a method of generating an automation script for executing a software test according to example embodiments.

[0032] FIG. **10**C is a diagram illustrating a method of training a large language model to understand software test cases and automation scripts according to example embodiments.

[0033] FIG. **10**D is a diagram illustrating a method of identifying a vulnerability in a software program and generating a fix for the vulnerability according to example embodiments.

[0034] FIG. **10**E is a diagram illustrating a method of identifying a new feature and generating source code for the new feature according to example embodiments.

[0035] FIG. **10**F is a diagram illustrating a method of detecting a security threat to a network and simulating intrusion of the security threat according to example embodiments.

[0036] FIG. **11** is a diagram illustrating a computing system that may be used in any of the example embodiments described herein.

DETAILED DESCRIPTION

[0037] It is to be understood that although this disclosure includes a detailed description of cloud computing, implementation of the teachings recited herein is not limited to a cloud computing environment. Instead, embodiments of the instant solution can be implemented in conjunction with any other computing environment now known or later developed.

[0038] The example embodiments are directed to a platform that can generate/design software tests, automation scripts for testing software, source code, software patches, and the like. In some embodiments, a generative artificial intelligence (GenAI) model may be trained to understand software tests, scripts, source code, and the like based on a large corpus of software tests, best practice documentation, software architecture documentation, and the like. The GenAI model may learn a correlation between text (e.g., words) and software test components, script components, and the like through the training process. Furthermore, the GenAI model may also generate new software tests based on descriptions thereof, such as a description of the requirements of the software test.

[0039] The example embodiments enable using GenAI models to enhance the test design process. This innovative approach facilitates requirement elaboration, test scenario design, and automated test script creation. By harnessing the power of generative AI, the example embodiments provide a system that can significantly reduce human intervention and errors while speeding up the test design phase.

[0040] Traditionally, a quality assurance engineer is responsible for maintaining the infrastructure needed for test execution, often resulting in a monolithic application. The platform described herein revolutionizes this process by providing a web service/cloud-based service that hosts multiple testing frameworks/programming languages, allowing tests to be executed on-demand (in any of the frameworks/programming languages) without requiring QA engineers to manage the infrastructure. This approach improves test development efficiency and enables seamless AI-powered test design process integration.

[0041] By leveraging the power of Generative AI and automation testing as a service, the example embodiments provide a platform that can significantly streamline the QA process, allowing for faster test design and execution. In addition, the system described herein can reduce human intervention within the test design process, thereby reducing the chances for human errors and inconsistencies, leading to more reliable and accurate test results. The platform also offers a scalable solution that can adapt to the ever-changing software development requirements, ensuring that the QA process remains efficient and effective. In addition, by eliminating the need for QA engineers to manage the infrastructure and reducing errors in the test design process, the system offers considerable cost savings for organizations.

[0042] According to various embodiments, the GenAI model may be a large language model (LLM), such as a multimodal large language model. As another example, the GenAI model may be a transformer neural network ("transformer") or the like. The GenAI model can understand connections between text and components (e.g., boxes, lines, arrows, software architecture, etc.) within software architecture drawings. For example, the GenAI model may include libraries and deep learning frameworks that enable the GenAI model to create software tests, activation scripts, source code, etc., based on text inputs.

[0043] By creating software tests from natural language descriptions, the GenAI model can relieve a user from generating such tests manually. Furthermore, the GenAI model described herein can learn activation scripts for executing the software tests "automatically" on the software program being tested.

[0044] Here, the GenAI model may build a software test and/or an automation script for executing the software test.

[0045] Furthermore, the GenAI model described herein can be integrated within a larger artificial intelligence system that includes machine learning and artificial intelligence models, other GenAI models, and the like. This system can perform additional functionality through the testing process/testing environment. For example, new product features can be identified based on the software program attributes being tested. As another example, security vulnerabilities can be detected from the testing, and repairs can be generated and even tested using a combination of models.

[0046] FIG. **1**A illustrates a GenAI computing environment **100** that includes a system for generating test cases according to example embodiments. In the example of FIG. 1A, the system includes a test execution service **130** that hosts a software testing environment and can execute software tests stored in a test repository **132**. In the example embodiments, the test execution service **130** can execute a test in any of multiple different frameworks/different programming languages, including PYTHON®, JAVA®, C++, and the like.

[0047] According to various embodiments, the test execution service **130** is coupled to a framework connector **140** (software program), which manages the execution of the software tests via a plurality of different frameworks **141**, **142**, **143**, and **144**. Each framework may include a collection of tools and software libraries necessary for the framework. Here, the framework connector can connect the test execution service **130** to the proper testing framework (from among the plurality of different frameworks **141**, **142**, **143**, and **144**) based on a user request or in an automated way. Each framework may create test scripts by developing required code or running commands in the test environment of the respective framework.

[0048] In addition, the system includes a GenAI model **120** trained to generate software test cases from input data. As another example, the GenAI model **120** may generate automation scripts for executing software test cases in an automated manner. As another example, the GenAI model **120** may generate source code such as code that can be used to repair a vulnerability in a software program, code that can be used to simulate a security threat such as a virus, cyber-attack, etc., and the like. The GenAI model **120** may be hosted by a host platform that also hosts the test execution service **130**. Further, the GenAI model **120** may communicate with the test execution service **130** directly via API calls or the like. In this example, the GenAI model **120** may include a data store **122** with a repository of software tests, automation scripts, source code, vulnerability code, software patches, and the like.

[0049] The data store **122** may be accessed during the execution of the GenAI model **120**.

[0050] In addition, the system includes a user interface **110** that is output by the test execution service **130**. For example, the user interface **110** may be included in a front-end of the software application shown on a user device **102** screen that accesses the host platform and the test execution service via a computer network such as the Internet. The user interface **110** may include controls that can be used to build software tests, perform software testing, develop automation scripts, and the like.

[0051] FIG. **1**B illustrates an example of a software test case **150** generated by the GenAI model **120** in FIG. **1**A, according to example embodiments. Referring to FIG. **1**B, the software test case **150** includes a diagram with a plurality of boxes/cells identifying the actions to be taken. For example, a first column **152** in the software test case includes a description of the overall purpose of the test case. In this case, the test case is a test of four separate text boxes on a graphical user interface of a software application that receives four input characters, each corresponding to a 16-digit payment card number.

[0052] The test case also includes additional components, including four input activities to be performed during testing, as indicated in the four cells in column **154**. The four input activities describe what will be performed during the testing input. In addition, the four input activities in the column **154** are paired with four expected results in column **156**. In this example, the software test also includes a column **158** for actual results observed during the testing process and a column **160** indicating each input activity's pass/fail status. Here, the four cells in column **158** are to be filled in by the test, and the four cells in column **160** are to be selected after the rest have been performed.

[0053] FIG. **2** illustrates a process **200** of executing a model **224** on input content according to example embodiments. For example, the model **224** may be the GenAI model **120** described concerning FIG. **1**A, however, embodiments are not limited to it.

[0054] Referring to FIG. **2**, a software application **210** may request execution of the model **224** by submitting a request to the host platform **220**. In response, an AI engine **222** may receive the request and trigger the model **224** to execute within a runtime environment of the host platform **220**.

[0055] In FIG. **2**, the AI engine **222** may control access to models stored within the model repository **223**. For example, the models may include GenAI models, AI models, machine learning models, neural networks, and/or the like. The software application **210** may trigger execution of the model **224** from the model repository **223** via submission of a call to an API **221** (application programming interface) of the AI engine **222**. The request may include an identifier of the model **224**, such as a unique ID assigned by the host platform **220**, a payload of data (e.g., to be input to the model during execution), and the like. The AI engine **222** may retrieve the model **224** from the model repository **223** in response, and deploy the model **224** within a live runtime environment. After the model is deployed, the AI engine **222** may execute the running instance of the model **224** on the payload of data, and return a result of the execution to the software application **210**.

[0056] In some embodiments, the data payload may be a format that cannot be input to the model **224** nor read by a computer processor. For example, the data payload may be text, image, audio, etc. In response, the AI engine **222** may convert the data payload into a format readable by the model **224**, such as a vector or other encoding.

[0057] The vector may then be input to the model **224**.

[0058] In some embodiments, the software application **210** may display a user interface that enables a user to provide feedback from the output provided by the model **224**. For example, a user may input a confirmation that the test case generated by a GenAI model is correct or includes incorrect content. This information may be added to the results of execution and stored within a log **225**. The log **225** may include an identifier of the input, an identifier of the output, an identifier of the model used, and feedback from the recipient. This information may be used to subsequently retrain the model.

[0059] FIG. **3**A illustrates a process **300**A of training a GenAI model **322** according to example embodiments. However, it should be appreciated that the process **300**A shown in FIG. **3**A also applies to other models, such as machine learning models, AI models, and the like. Referring to FIG. **3**A, a host platform **320**, may host an IDE **310** (integrated development environment) where GenAI models, machine learning models, AI models, and the like may be developed, trained, retrained, and the like. In this example, the IDE **310** may include a software application with a user interface accessible by a user device over a network or through a local connection.

[0060] For example, the IDE **310** may be embodied as a web application that can be accessed at a network address, URL, etc., by a device. As another example, the IDE **310** may be locally or remotely installed on a computing device used by a user.

[0061] The IDE **310** may be used to design a model (via a user interface of the IDE), such as a generative artificial intelligence model that can receive text as input and generate custom imagery, etc. The model can then be executed/trained based on the training data established via the user interface. For example, the user interface may be used to build a new model. The training data for training such a new model may be provided from a training data store such as a database **324**, which includes training samples from the web, customers, and the like. As another example, the training data may be pulled from one or more external data stores **330** such as publicly available sites, etc.

[0062] The GenAI model **322** may be executed on training data via an AI engine **321** of the host platform **320** during training. The training data may include a large corpus of text from software tests, best practice documentation, compliance documentation, etc. In the example embodiments, the training data may include software tests, source code, activation scripts, best practice documentation, compliance documentation, etc. The GenAI model **322** may learn mappings/connections between requirements associated with a software test and the components included within the software test case and can thus create software test cases from a description of the requirements of the software test case. When fully trained, the model may be stored within the model repository **323** via the IDE **310** or the like.

[0063] As another example, the IDE **310** may be used to retrain the GenAI model **322** after the model has already been deployed. Here, the training process may use executional results that have already been generated/output by the GenAI model **322** in a live environment (including any customer feedback, etc.) to retrain the GenAI model **322**. For example, predicted outputs/images custom generated by the GenAI model **322** and the user feedback of the images may be used to retrain the model to enhance the images generated for all users. The responses may indicate whether the generated software architecture diagram is correct and, if not, what aspects of the diagram are incorrect. This data may be captured and stored within a runtime log **325** or other datastore within the live environment and can be subsequently used to retrain the GenAI model **322**.

[0064] FIG. **3**B illustrates a process **300**B of executing a training process for training/retraining the GenAI model **322** via an AI engine **321**. In this example, an executable script **326** is developed and configured to read data from a database **324** and input the data to the GenAI model **322** while the GenAI model is running/executing via the AI engine **321**.

[0065] For example, the executable script **326** may use identifiers of data locations (e.g., table IDs, row IDs, column IDs, topic IDs, object IDs, etc.) to identify locations of the training data within the database **324** and query an API **328** of the database **324**. In response, the database **324** may receive the query, load the requested data, and return it to the AI engine **321**, which is input to the GenAI model **322**. The process may be managed via a user interface of the IDE **310**, which enables a human-in-the-loop during the training process (supervised learning). However, it should also be appreciated that the system is capable of unsupervised learning.

[0066] The executable script **326** may iteratively retrieve additional training data sets from the database **324** and iteratively input the additional training data sets into the GenAI model **322** during the execution of the model to continue to train the model. The script may continue until instructions within the script tell the script to terminate, which may be based on a number of iterations (training loops), total time elapsed during the training process, etc.

[0067] FIG. **3**C illustrates a process **300**C of designing a new AI model via a user interface **340** according to example embodiments. For example, the user interface **340** may be output as part of the software application that interacts with the IDE **310** shown in FIG. **3**A, however, embodiments are not limited to it. Referring to FIG. **3**C, a user can use an input mechanism to make selections from a menu **342** shown on the left-hand side of the user interface **340** to add pieces to the model such as data components, model components, analysis components, etc., within a workspace **344** of the user interface **340**.

[0068] In the example of FIG. **3**C, the menu **342** includes a plurality of graphical user interface (GUI) menu options, which can be selected to drill down into additional components that can be added to the model design shown in the workspace **344**.

[0069] Here, the GUI menu options include options for adding features such as neural networks, machine learning models, AI models, data sources, conversion processes (e.g., vectorization, encoding, etc.), analytics, etc. The user can continue to add features to the model and connect them using edges or other means to create a flow within the workspace **344**. For example, the user may add a node **346** to a new model diagram within the workspace **344**. For example, the user may connect the node **346** to another node in the diagram via an edge **348**, creating a dependency within the diagram. When the user is done, the user can save the model for subsequent training/testing.

[0070] According to various embodiments, the GenAI model described herein may be trained based on custom-defined prompts designed to draw out specific attributes associated with a software test, automation script, vulnerability, or the like. These same prompts may be output during the live execution of the GenAI model. For example, a user may input a software test description, such as the requirements that the software test will be expected to perform when testing a software program. The GenAI model can then use the requirements to generate a new software test. The prompts may be generated via prompt engineering that can be performed through the model training process, such as the model training process described above in the examples of FIGS. **3A-3C**.

[0071] Prompt engineering is the process of structuring sentences (prompts) so that the GenAI model understands them. A prompt may ask for and receive a description of a testing feature to be included in a software test. The text may be input to the GenAI model and used to create a new software test that can be used to perform the testing feature described in the response to the prompt. Part of the prompting process may include delays/waiting times intentionally included within the script so the model has time to think/understand the input data.

[0072] FIG. **4** illustrates a process **400** of a GenAI model **422** generating an architecture diagram **424** of a software architecture based on prompts and responses to the prompts according to example embodiments.

[0073] Referring to FIG. **4**, the GenAI model **422** may be hosted by a host platform and may be part of a software application **420** that is also hosted on the host platform. Here, the software application **420** may establish a connection with a user device **410**, such as a secure network connection. The secure connection may include a PIN, biometric scan, password, username, TTL handshake, etc.

[0074] In the example of FIG. **4**, the software application **420** may control the interaction of the GenAI model **422** on the host platform and the user device **410**. In this example, the software application **420** may output queries on a user interface **412** of the user device **410** with user information requests. The user may enter values into the fields on the user interface corresponding to the queries and submit/transfer the data to the software application **420**, for example, by pressing a submit button, etc. In this example, the application may combine the query with the response from the user interface and generate a prompt submitted to the GenAI model **422**. For example, each prompt may include a combination of a query on the UI plus the response from the user. For example, if the query is "Describe the Requirements of the Test" and the response is "The test should check to make sure that the 16-digit input field on the GUI can only accept 16 digits", then the text from both the prompt and the response to the prompt may be submitted to the GenAI model **422**.

[0075] In some embodiments, the software application **420** may deliberately add waiting times between submitting prompts to the GenAI model **422** to ensure the model has enough time to "think" about the answer. The waiting times may be integrated into the code of the software application **420**, or they may be modified/configured via a user interface. Furthermore, the ordering of the prompts and the follow-up questions may differ depending on the answers given during the previous prompt or prompts. The content within the prompts and the ordering of the prompts can cause the GenAI model **422** to generate software tests, automation scripts, source code, or the like.

[0076] FIGS. **5A-5D** illustrate a process of generating a software test according to example embodiments. For example, the process may be performed by the host platform **520**, shown in the example of FIG. **1A**, but the embodiments are not limited to it. For example, FIG. **5A** illustrates a computing environment **500** of a host platform **520** that generates a software test **530** based on text data input via a user interface **512**.

[0077] In this example, the host platform **520** hosts a testing software **522** that a user can interact with via the user interface **512**. Here, the host platform **520** may include a web server, cloud platform, on-premises server, or the like, while the user interface **512** may be displayed on a screen of a user device such as a mobile device, laptop, tablet, or the like, which is network-connected to the host platform **620**.

[0078] In this example, the testing software **522** includes various data stores that can be accessed when testing software programs. For example, a software test repository **526** may store software tests and related documentation, including best practices.

[0079] As another example, a test data database **527** may store test data that can be used by the software tests stored within the software test repository **526** during testing. In addition, the host platform **520** also includes a script database **528** that stores automation scripts that enable the software tests to be performed/executed in an automated manner.

[0080] According to various embodiments, the host platform **520** also hosts a generative artificial intelligence (GenAI) model **524** capable of generating a software test based on inputs received via the user interface **512**. For example, the GenAI model **524** may be trained on a large corpus of software tests and software test documentation and can receive a description of a software test, such as the requirements of the test, and generate a software test document (e.g., the software test **530**) that includes a set of instructions to be performed, expected results, and content areas that can be left blank for insertion by the user during testing. An example of the software test **530** is shown in FIG. **1B**, however, embodiments are not limited to it. It should be appreciated that the software test may have a different format, a different style, images, and the like.

[0081] FIG. **5B** illustrates a process **540** of generating a sequence of steps based on generative AI according to example embodiments. Referring to FIG. **5B**, in this example, a user may submit a list of requirements or features of the software program that the user wishes to test.

[0082] The requirements may include a list of software functions, components, etc., that are to be tested and a description of the activities to be performed to carry out the test and what should happen when the activities are carried out.

[0083] For example, the requirements entered by the user may be the requirement mentioned already: "The test should check to make sure that the 16-digit input field on the GUI can only accept 16 digits." In response, the GenAI model **524** may generate a sequence of steps, including step **542**, a step **544**, a step **546**, and a step **548**. Here, the steps may be determined by the GenAI model **524** based on historical software tests that have had similar requirements that the GenAI model has learned from. In this example, the steps, including the step **542**, the step **544**, the step **546**, and the step **548**, are displayed on the user interface **512**, where the user of the user device can view the steps and provide feedback or accept the steps. Each step is another step during the test of the software program.

[0084] For example, FIG. **5C** illustrates a process **550** of generating a new software test from the steps shown on the user interface in FIG. **5B**. Referring to FIG. **5C**, a user may press a submit button **549** on the user interface **512** or otherwise accept the steps shown on the user interface for inclusion in a software test. In response, the system described herein inputs the steps on the user interface **512** into a new software test **552**, which includes the steps shown on the user interface, including the step **542**, the step **544**, the step **546**, and the step **548**, as well as the order in which the sequence of steps are in. For example, the host platform **520** may generate a document, an XML file, a JSON, etc., describing the steps.

[0085] In some embodiments, the GenAI model **524** may generate other attributes associated with the new software test **552**, including an activation script for executing the new software test **552** in an automated manner, a description/label for the new software test **552**, and the like. An example of generating an automation script is further described in the examples of FIGS. **6**A-**6**C. Referring again to FIG. **5**C, the new software test **552** may include a description **554** of the overall theme or purpose of the test, which is also generated by the GenAI model **524** and added/appended to the new software test **552** as a label. The description **554** can be searched by a search engine or other software program when searching for software tests to perform.

[0086] Here, the host system may store the new software test **552** paired with the description **554** in the software test repository **526**.

[0087] FIG. **5**D illustrates a process **560** of executing the new software test **552** and showing the software test via an image **562** on a user interface **570** of a software application such as an integrated development environment (IDE).

[0088] As noted, the description **554** added to the new software test **552** may be used to search the software test repository **526** for and select a software test based on a search term input from the user interface **570**. Each software test stored in the software test repository **526** may include a label/description with keywords associated with the test that can be searched by the testing software **522**. Furthermore, the testing software **522** may launch/execute a software program to be tested and also launch an automation script **564**, which automates the execution of the software test on the software program. The results may be displayed via the user interface **570**.

[0089] FIGS. **6**A-**6**C are diagrams illustrating a process of generating an automation test script according to example embodiments.

[0090] For example, FIG. **6**A illustrates a computing environment **600** for generating an automation script **630** for automating the execution of a software test (not shown), such as the software test **530** in FIG. **5**A, or the like. In this example, the process may be performed by a host platform **620** that is the same as or similar to the host platform **520** shown in FIG. **5**A, but the embodiments are not limited to it. For example, FIG. **6**A illustrates a computing environment **600** of a host platform **620** that generates an automation script **630** based on text data input via a user interface **612**. In this example, the host platform **620** hosts a testing software **622** that a user can interact with via the user interface **612**. The host platform **620** may include a web server, cloud platform, on-premises server, or the like, while the user interface **612** may be displayed on a screen of a user device such as a mobile device, laptop, tablet, or the like, which is network-connected to the host platform **620**.

[0091] According to various embodiments, the host platform **620** also hosts a generative artificial intelligence (GenAI) model **624** capable of generating an automation script for automating the execution of a software test based on inputs received via the user interface **612**. For example, the GenAI model **624** may be trained on a large corpus of automation scripts, software tests, scripting best practices, and the like, and can receive a description of a software test, such as the requirements of the test, and generate a list of features to be performed by the software test.

[0092] The list of features or steps may be used to build an automation script for executing the software test with little or no user involvement.

[0093] In this example, the GenAI model **624** may ingest training materials from a repository of software test s **626**, a database of test data **627**, a repository of automation scripts **628**, or the like, as well as the requirements input by the user on the user interface **612**.

[0094] The model may use these inputs to build a step definition. For example, FIG. **6**B illustrates a process **640** of generating a step file with a list of steps (also called a step definition). Here, the GenAI model **624** may generate a step **642**, a step **644**, and a step **646**, which are to be performed by the script, and code to be executed by the script to carry out the step.

[0095] In the example of FIG. **6**B, pseudo-code is shown, but it should be appreciated that actual source code may be stored within the step definition.

[0096] According to various embodiments, the sequence of steps (step definition) may include mappings between each step/scenario within the software test and the code function to be executed by the script. The step definition can be thought of as the automation script. It can be encoded and executed by a computer processor. When the testing software executes the step definition, it scans the step definition and identifies which function to call/execute based thereon.

[0097] FIG. **6**C illustrates a process **650** of executing a software test via the testing software **622** based on the automation script **630** generated in FIG. **6**A.

[0098] Here, the testing software **622** reads the step definition from the automation script, held in the repository of automation scripts **628**. The testing software **622** can map the next step to be performed within the software test to the corresponding code module in the automation script and identify the code function(s) to execute and executes it. This process continues for each activity in the software test, paired with a step in the automation script. Thus, the order/sequence of steps can be maintained.

[0099] FIGS. **7**A-**7**C illustrate a process of identifying and testing a software vulnerability according to example embodiments. For example, FIG. **7**A illustrates a process **700** of a user being prompted about an issue they are experiencing with a software program. For example, the software program may be a software program being tested via the testing software **622** shown in FIG. **6**A or the testing software **522** shown in FIG. **5**A.

[0100] Referring to FIG. **7**A, the user may be using a security application **720** hosted by a host platform (not shown).

[0101] The security application **720** may have a user interface **730** that is accessible and displayed on a screen of a user device (not shown) that is network-connected to the host. The security application **720** also includes a GenAI model **722** trained to generate source code.

[0102] In the example of FIG. **7**A, the GenAI model **722** may receive a request from the user with a software error notification.

[0103] In response, the GenAI model **722** may prompt the user with various prompts **732** and **736** and receive a response from fields **734** and **738** on the user interface **730**. The combination of the prompts and the responses extracted from the fields **734** and **738** may be input into the GenAI model **722**. The inputs can be used by the GenAI model **722** to determine a security vulnerability with the software program being tested.

[0104] According to various embodiments, the GenAI model **722** may generate source code based on the determined security vulnerability.

[0105] For example, the GenAI model **722** may consume source code of known vulnerabilities from a code repository **710**, best practices documentation from a database **712**, a database of software patches/fixes **714**, which includes a description of the problems and the source code used to repair the problems. The GenAI model **722** may learn from and use the code and best practice recommendations to generate new source code, as shown in the example of FIG. **7**B.

[0106] In particular, FIG. **7**B illustrates a process **740** of generating new source code **742** and displaying it on a screen (e.g., the user interface **730**). For example, the GenAI model **722** may consume source code and/or best practice documentation during runtime or during training and use the knowledge therein to generate new source code. In this example, the new source code **742** includes a repair, patch, fix, etc., for the security vulnerability detected by the GenAI model **722** in FIG. **7**B. The source code may include methods, functions, calls, etc. The user may be allowed to accept the code or reject the code.

[0107] For example, FIG. **7**C illustrates a process **750** of the new source code **742** being inserted into source code **762** of the software program. Referring to FIG. **7**C, the user may accept the repair code by pressing an accept button **754** or the like on the user interface **730**. In response, the security application **720** may identify a location for the new source code **742** within the source code **762**, insert it therein, and store the source code **762** with its updates/modifications in a code repository **760** of the host platform.

[0108] FIGS. **8**A-**8**C illustrate a process of generating new features for a software application based on software testing according to example embodiments. For example, FIG. **8**A illustrates a process **800** of multiple users testing software via a common software application (testing software) hosted on a host platform **820**. According to various embodiments, multiple users may access and use the testing software **822** shown in FIG. **8**A. During this process, the users may run tests via user interfaces **812** on different aspects of a software application or multiple software applications.

[0109] For example, software tests may be retrieved from a test case repository **824**, and test data for the software tests may be retrieved from a test data database **825**. Furthermore, an automation script may be retrieved from a script repository **826** to execute the software tests in an automated manner.

[0110] During the testing processes, the testing software **822** may log the testing results into a log database **828**, including the tests performed, the outputs, the pass/fail status, and the like. This data contains valuable information that can be used to develop new features about the software being tested. For example, the log data stored in the log database **828** may contain information about the software's features being tested and the frequency at which the features are being tested. Features being tested more frequently may be ideal for replacement.

[0111] According to various embodiments, a GenAI model may suggest new features or replacement features for a software application based on the logged testing data. For example, FIG. **8**B illustrates a process **830** of a machine learning model **832** receiving the logged data from the log database **828**, which is from testing a particular software program via the testing software **822** shown in FIG. **8**A.

[0112] The logged data may be input to a machine learning model **832**, which is trained to identify new features for a software application, such as new buttons or controls on the user interface, new methods, new APIs, new code modules, etc.

[0113] In this example, the machine learning model **832** may include a language model or a large language model that can receive text from the log database **828** and identify a new feature to be added.

[0114] Also, the description of the new feature may be output by the machine learning model **832** and input to a GenAI model **834**. Here, the GenAI model **834** may receive the description of the new feature and generate source code for adding the new feature to the software program. The source code may be generated based on source code examples stored in a code repository **836** and best practice documentation stored in a database **838**. Here, the resulting source code generated by the GenAI model **834** may be displayed on a user interface **840**, which may be viewed on a user device. For example, the new source code may include source code **842**, shown on the user interface **840** in FIG. **8**C.

[0115] FIG. **8**C illustrates a process **850** of testing the source code **842** generated by the GenAI model **834** and displayed on the user interface **840**. Here, a user may press a "test" button **844** on the user interface **840** or the like, which causes the testing software **822** to execute a software test on the source code **842**. In some embodiments, the user may choose the software test, which the GenAI model may automatically generate or select. Here, the testing software **822** may use software tests stored in the test case repository **824**, test data stored in the test case database **825**, and/or an automation script included in the script repository **826**.

[0116] FIGS. **9**A-**9**B illustrate a process of detecting and simulating the security threat on a computer network according to example embodiments. For example, FIG. **9**A illustrates a process **900** of a plurality of user devices, including user device **902**, user device **904**, and user device **906**, accessing a software application **922** hosted on a host platform **920**. Here, the users may access the software application **922** to access user accounts and other data held in an application database **924**.

[0117] In this example, the user devices may communicate with the software application **922** over a computer network such as the Internet, subject to security issues. For example, the user devices may download data, upload data, send network communications, and the like over a public network. During this time, the communications between the user devices and the host platform **920** may be monitored and stored within a log database **926** within the runtime environment. In this example, the log may describe the communications, requests, responses, client-server interactions, and the like.

[0118] According to various embodiments, a machine learning model **928** may be executed on the communication history data stored in log data stored in the log database **926** to identify a potential threat to the network on which the host platform **920** operates. The potential threat may include a virus, phishing, brute force, or other cyber threats. In this example, the machine learning model **928** can identify the potential threat and notify a GenAI model **932**, as shown in FIG. **9**B.

[0119] For example, FIG. **9**B illustrates a process **930** of installing the potential security threat in a system, such as a digital twin, associated with the host platform. Referring to FIG. **9**B, the GenAI model **932** may receive an identifier of the potential threat and generate source code **936** that mimics the threat.

[0120] For example, the GenAI model **932** may access a source code repository and use that to generate the potential threat.

[0121] Furthermore, the host platform **920** may launch a digital twin **934** of the host platform, the computer network, a particular device, or a combination of devices and install the source code **936** for the security threat.

[0122] This process may be performed via a security software program **940** on the host platform **920**, which executes a simulation of the security threat on the digital twin **934**. The digital twin **934** may be generated ahead of time and may be ready for the source code **936**.

[0123] FIG. **10**A is a diagram illustrating a method of generating a software test case using GenAI according to example embodiments. For example, the method **1000** may be performed by a host platform such as a web server, cloud platform, on-premises server, or the like.

[0124] Referring to FIG. **10**A, in **1001**, the method may include receiving a request to test a software program from a user device, the request comprising a description of requirements of the software program. In **1002**, the method may include generating a plurality of testing elements based on the execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases. In **1003**, the method may include generating a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model. In **1004**, the method may include storing the test case within a storage device.

[0125] In some embodiments, the method may further include displaying the plurality of testing elements via a user interface, receiving approval of the plurality of testing elements via the user interface, and, in response to the received approval, generating the test case comprising the plurality of testing elements. In some embodiments, the method may include generating and outputting a prompt on a user interface of the user device and receiving a response to the prompt from the user interface. In some embodiments, the method may include generating the plurality of testing elements for the test case based on the execution of the GenAI model on the prompt and the response to the prompt.

[0126] In some embodiments, the generating the plurality of test steps may include generating a description of a plurality of actions to be performed by a user during the performance of the test case, and generating the test case comprises storing the description of the plurality of actions within a document. In some embodiments, the test case may include perquisites, an objective, references, and test steps generated by the GenAI model based on the execution of the GenAI model on the descriptions of the requirements of the software program and the repository of test cases. In some embodiments, the method may further include displaying the test case generated by the GenAI model on the user interface and receiving feedback about the test case via the user interface. In some embodiments, the method may further include training the GenAI model based on execution of the GenAI model on the test case and the received feedback about the test case.

[0127] FIG. **10**B is a diagram illustrating a method of generating an automation script for executing a software test according to example embodiments. For example, the method **1010** may be performed by a host platform such as a web server, cloud platform, on-premises server, or the like. Referring to FIG. **10**B, in **1011**, the method may include receiving a description of a plurality of testing elements for testing a software program and storing the software test within a storage device. In **1012**, the method may include generating an automation script for automating execution of the software test based on execution of a generative artificial intelligence model (GenAI) model on the plurality of testing elements and a repository of automation scripts. In **1013**, the method may include attaching the automation script to the software test within the storage device. In response to a request to execute the software test, in **1014**, the method may include executing the plurality of testing elements within the software test based on the attached automation script.

[0128] In some embodiments, the method may further include displaying results of the execution of the plurality of testing elements via a user interface. In some embodiments, the method may include generating a description of a plurality of features to be included within the software test based on the received requirement and generating the automation script based on the execution of the GenAI model on the plurality of features. In some embodiments, the method may include generating a step definition based on the requirement generated in a predefined programming language.

[0129] In some embodiments, the generating may include generating the automation script in the predefined programming language based on the step definition. In some embodiments, the method may further include training the GenAI model to understand connections between features and source code by executing the GenAI model on mappings between a plurality of features and a plurality of code modules, respectively. In some embodiments, the automation script may include generating an executable software program that executes the plurality of testing elements in sequence via a software application's user interface. In some embodiments, the request may include an identifier of a programming language, and the executing comprises executing the software test via a framework developed in the identified programming language.

[0130] FIG. **10**C is a diagram illustrating a method of training a large language model to understand software test cases and automation scripts according to example embodiments. For example, the method **1020** may be performed by a host platform such as a web server, cloud platform, on-premises server, or the like. Referring to FIG. **10**C, in **1021**, the method may include generating a large language model via a user interface. In **1022**, the method may include executing the large language model on a repository of software test cases and requirements of the software test cases to train the large language model to understand connections between test case components and test case requirements. In **1023**, the method may include receiving a description of the features of a software program to be tested. In **1024**, the method may include, in response to receiving the description of the features, generating a software test case based on the execution of the large language model on the received descriptions and displaying the software test case via the user interface.

[0131] In some embodiments, the method may include receiving user feedback about the software test case via the user interface and executing the large language model on the software test case and the feedback to further train the large language model. In some embodiments, the method may further include receiving a call via an application programming interface (API) with an identifier of a programming language and, in response, generating the software test case for the software program within the identified programming language. In some embodiments, the executing may further include executing the large language model on best practices documents of software test cases to further train the large language model to understand best practices.

[0132] In some embodiments, the method may include generating and outputting a prompt on the user interface during the training and receiving a response via the user interface. In some embodiments, the executing may include training the large language model based on the prompt output on the user interface and the response to the prompt received via the user interface. In some embodiments, the generating may include generating a plurality of test components of the software test, including a test specification, a test execution, a test recording, and a test verification based on the execution of the GenAI model. In some embodiments, the generating may include generating a respective requirement for each component within the software test based on the execution of the large language model on the received descriptions.

[0133] FIG. **10**D illustrates a method **1030** of identifying a vulnerability in a software program and generating a fix for the vulnerability according to example embodiments. For example, the method **1030** may be performed by a host platform such as a web server, cloud platform, on-premises server, or the like. Referring to FIG. **10**D, in **1031**, the method may include receiving, via a user interface, a request to test a software program. In **1032**, the method may include reading source code of the software program and identifying a vulnerability in the source code based on the reading. In **1033**, the method may include generating repair code for fixing the identified vulnerability based on execution of a generative artificial intelligence (GenAI) model on the source code and a repository of repair code used to repair previous vulnerabilities. In **1034**, the method may include displaying information about the repair code via the user interface.

[0134] In some embodiments, the method may include executing the GenAI model based on the source code and the repository of repair code to code for a new software component to address the vulnerability and display the generated source code of the new software component via the user interface. In some embodiments, the method may include receiving an input via the user interface with a confirmation of the repair code and, in response, inserting the repair code into the software program's source code. In some embodiments, the method may include generating one or more prompts based on the execution of the GenAI model on the source code and the repository of repair code and displaying the one or more prompts via the user interface.

[0135] In some embodiments, the method may include receiving a natural language response to the one or more prompts and generating the repair code based on execution of the GenAI model on the one or more prompts and the natural language response. In some embodiments, the software vulnerability may include one or more of a missing software component, an incorrect software component, and a malicious software component. In some embodiments, the generating may include modifying an existing software component of the software program as the repair code based on the execution of the GenAI model on the source code and the repository of repair code. In some embodiments, the method may include generating source code for changing the existing software component of the software program based on the execution of the GenAI model on a repository of software fixes.

[0136] FIG. **10**E illustrates a method **1040** of identifying a new feature and generating source code for the new feature according to example embodiments. For example, the method **1030** may be performed by a host platform such as a web server, cloud platform, on-premises server, or the like.

[0137] Referring to FIG. **10**E, in **1041**, the method may include executing tests on a software application via a test environment of a test platform and logging the results of the tests in a log file. In **1042**, the method may include identifying a new feature to be added to the software application based on the execution of a machine learning model on logged results of the tests stored in the log file.

[0138] In **1043**, the method may include generating source code for the new feature to be added to the software application based on the execution of a generative artificial intelligence (GenAI) model on the new feature and a repository of source code. In **1044**, the method may include displaying the generated source code via a user interface of the software application.

[0139] In some embodiments, the method may include adding the generated source code for the new feature to the existing source code of the software application to generate an updated software application and storing the updated software application in a software repository. In some embodiments, the method may further include a description of the new features based on the execution of the GenAI model on the new feature and the repository of source code and storing the description with the generated source code in a file on a storage device. In some embodiments, the method may include executing the generated source code, executing one or more test cases to generate test results, and displaying the test results via the software application's user interface.

[0140] In some embodiments, the method may include generating the one or more test cases based on execution of the GenAI model on the generated source code and one or more repositories of sample test cases. In some embodiments, the identifying may include identifying a new input mechanism to be added to the software application's user interface based on the execution of the machine learning model, and the generating comprises generating source code for the new input mechanism on the user interface. In some embodiments, the executing the tests on the software application via the test environment may include executing tests on the software application simultaneously while identifying the new feature to be added. In some embodiments, the generating the source code may include modifying an existing code module of the software application to perform the new feature and displaying the modified code module via the user interface.

[0141] FIG. **10**F illustrates a method **1050** of detecting a security threat to a network and simulating intrusion of the security threat according to example embodiments. For example, the method **1050** may be performed by a host platform such as a web server, cloud platform, on-premises server, or the like. Referring to FIG. **10**F, in **1051**, the method may include monitoring communications with user devices over a shared computer network. In **1052**, the method may include detecting a security threat from the monitored communications. In **1053**, the method may include generating a software program to simulate the security threat over the shared computer network based on execution of a generative artificial intelligence (GenAI) model on a description of the security threat and a source code repository. In **1054**, the method may include installing the source code for simulating the security threat on a system associated with the computer network. In **1055**, the method may include executing the source code for simulating the security threat via the system.

[0142] In some embodiments, the method may include recording network communications between the user devices via a log and detecting the security threat based on execution of a machine learning model on the log. In some embodiments, the method may include generating the description for the security threat based on execution of the machine learning model on the log of the monitored communications. In some embodiments, the monitoring may include monitoring communications between the user devices and a software application hosted on a host platform, and the detecting comprises detecting a vulnerability in the software application hosted by the host platform based on responses from the software application to the user devices.

[0143] In some embodiments, the communications may include one or more of client-server communications, network payloads, and network traffic patterns that occur on the shared computer network. In some embodiments, the installing may include installing the source code for simulating the security threat within a digital twin of the shared computer network and executing the installed source code via the digital twin of the shared computer network. In some embodiments, the installing may include installing the source code for simulating the security threat within a system on a different computer network and executing the source code on the shared computer network via the system on the different computer network. In some embodiments, the method may include generating a software patch for fixing the security threat based on execution of the GenAI model on results of the execution of the source code for simulating the security threat and storing the software patch in a storage device.

[0144] The above embodiments may be implemented in hardware, a computer program executed by a processor, firmware, or a combination of the above. A computer program may be embodied on a computer-readable medium, such as a storage medium. For example, a computer program may reside in random access memory ("RAM"), flash memory, read-only memory ("ROM"), erasable programmable read-only memory ("EPROM"), electrically erasable programmable read-only memory ("EEPROM"), registers, hard disk, a removable disk, a compact disk read-only memory ("CD-ROM"), or any other form of storage medium known in the art.

[0145] An exemplary storage medium may be coupled to the processor such that the processor may read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an application-specific integrated circuit ("ASIC"). In the alternative, the processor and the storage medium may reside as discrete components. For example, FIG. **11** illustrates an example computer system architecture, which may represent or be integrated into any of the above-described components, etc.

[0146] FIG. **11** illustrates an example system **1100** that supports one or more of the example embodiments described and/or depicted herein. The system **1100** comprises a computer system/server **1102**, which is operational with numerous other general-purpose or special-purpose computing system environments or configurations. Examples of well-known computing systems, environments, and/or configurations that may be suitable for use with computer system/server **1102** include but are not limited to, personal computer systems, server computer systems, thin clients, thick clients, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set-top boxes, programmable consumer electronics, network PCs, minicomputer systems, mainframe computer systems, and distributed cloud computing environments that include any of the above systems or devices, and the like.

[0147] Computer system/server **1102** may be described in the general context of computer system-executable instructions, such as program modules, being executed by a computer system. Generally, program modules may include routines, programs, objects, components, logic, data structures, and so on that perform particular tasks or implement particular abstract data types. Computer system/server **1102** may be practiced in distributed cloud computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed cloud computing environment, program modules may be located in local and remote computer system storage media, including memory storage devices.

[0148] As shown in FIG. **11**, computer system/server **1102** in the example system **1100** is shown as a general-purpose computing device. The computer system/server **1102** components may include, but are not limited to, one or more processors or processing units (processor **1104**), a system memory **1106**, and a bus that couples various system components, including the system memory **1106** to the processor **1104**.

[0149] The bus represents one or more of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using various bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnects (PCI) bus.

[0150] Computer system/server **1102** typically includes various computer system-readable media. Such media may be any available media that is accessible by computer system/server **1102**, and it includes both volatile and non-volatile media, removable and non-removable media. The system memory **1106**, in one embodiment, implements the flow diagrams of the other figures. The system memory **1106** can include computer system readable media in the form of volatile memory, such as random-access memory (RAM) **1110** and/or cache memory **1112**. Computer system/server **1102** may include other removable/non-removable, volatile/non-volatile computer system storage media. By way of example only, storage system **1114** can be provided for reading from and writing to a non-removable, non-volatile magnetic media (not shown and typically called a "hard drive"). Although not shown, a magnetic disk drive for reading from and writing to a removable, non-volatile magnetic disk (e.g., a "floppy disk") and an optical disk drive for reading from or writing to a removable, non-volatile optical disk such as a CD-ROM, DVD-ROM or other optical media can be provided. In such instances, each can be connected to the bus by one or more data media interfaces. As further depicted and described below, the system memory **1106** may include at least one program product with a set (e.g., at least one) of program modules configured to carry out the functions of various embodiments of the application.

[0151] Program/utility **1116**, having a set (at least one) of program modules **1118**, may be stored in the system memory **1106** by way of example, and not limitation, as well as an operating system, one or more application programs, other program modules, and program data. Each of the operating system, one or more application programs, other program modules, and program data or some combination thereof may include an implementation of a networking environment. Program modules **1118** generally carry out the functions and/or methodologies of various embodiments of the application as described herein.

[0152] As will be appreciated by one skilled in the art, aspects of the present application may be embodied as a system, method, or computer program product. Accordingly, aspects of the present application may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.), or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the present application may be a computer program product embodied in one or more computer-readable medium(s) having computer-readable program code embodied thereon.

[0153] Computer system/server **1102** may also communicate with one or more external devices **1120** such as a keyboard, a pointing device, a display **1122**, etc.; one or more devices that enable a user to interact with computer system/server **1102**; and/or any devices (e.g., network card, modem, etc.) that enable computer system/server **1102** to communicate with one or more other computing devices. Such communication can occur via I/O interfaces **1124**. Still yet, computer system/server **1102** can communicate with one or more networks, such as a local area network (LAN), a general wide area network (WAN), and/or a public network (e.g., the Internet) via network adapter **1126**. As depicted, network adapter **1126** communicates with the other components of the computer system/server **1102** via a bus. It should be understood that although not shown, other hardware and/or software components could be used in conjunction with computer system/server **1102**. Examples include, but are not limited to, microcode, device drivers, redundant processing units, external disk drive arrays, RAID systems, tape drives, and data archival storage systems, etc.

[0154] Although an exemplary embodiment of at least one of a system, method, and computer-readable medium has been illustrated in the accompanying drawings and described in the foregoing detailed description, it will be understood that the application is not limited to the embodiments disclosed but is capable of numerous rearrangements, modifications, and substitutions as set forth and defined by the following claims. For example, the system's capabilities of the various figures can be performed by one or more of the modules or components described herein or in a distributed architecture and may include a transmitter, receiver, or pair of both. For example, all or part of the functionality performed by the individual modules may be performed by one or more of these modules. Further, the functionality described herein may be performed at various times and about various events, internal or external to the modules or components. Also, the information sent between various modules can be sent between the modules via at least one of a data network, the Internet, a voice network, an Internet Protocol network, a wireless device, a wired device, and/or via a plurality of protocols. Also, the messages sent or received by any of the modules may be sent or received directly and/or via one or more of the other modules.

[0155] One skilled in the art will appreciate that a "system" could be embodied as a personal computer, a server, a console, a personal digital assistant (PDA), a cell phone, a tablet computing device, a smartphone, or any other suitable computing device, or combination of devices. Presenting the above-described functions as being performed by a "system" is not intended to limit the scope of the present application but to provide one example of many embodiments. Indeed, methods, systems, and apparatuses disclosed herein may be implemented in localized and distributed forms consistent with computing technology.

[0156] It should be noted that some of the system features described in this specification have been presented as modules to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising 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, graphics processing units, etc.

[0157] A module may also be at least partially implemented in software for execution by various types of processors. An identified unit of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions that may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together but may comprise disparate instructions stored in different locations, which, when joined logically together, comprise the module and achieve the stated purpose for the module. Further, modules may be stored on a computer-readable medium, which may be, for instance, a hard disk drive, flash device, random access memory (RAM), tape, or any other such medium used to store data.

[0158] Indeed, a module of executable code could be a single instruction or many instructions and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated within modules embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set or may be distributed over different locations, including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network.

[0159] It will be readily understood that the application components, as generally described and illustrated in the figures herein, may be arranged and designed in various configurations. Thus, the detailed description of the embodiments is not intended to limit the scope of the application as claimed but is merely representative of selected embodiments of the application.

[0160] One with ordinary skill in the art will readily understand that the above may be practiced with steps in a different order and/or hardware elements in configurations that are different from those disclosed. Therefore, although the application has been described based on these preferred embodiments, certain modifications, variations, and alternative constructions would be apparent to those of skill in the art.

[0161] While preferred embodiments of the present application have been described, it is to be understood that the embodiments described are illustrative only, and the scope of the application is to be defined solely by the appended claims when considered with a full range of equivalents and modifications (e.g., protocols, hardware devices, software platforms, etc.) to it.

What is claimed is:

1. An apparatus comprising:

a memory;

a network interface configured to receive a request to test a software program stored in the memory from a user device, the request comprising a description of requirements of the software program; and

a processor coupled to the memory and the network interface, the processor configured to:

generate a plurality of testing elements based on execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases,

generate a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model, and

store the test case within the memory.

2. The apparatus of claim **1**, wherein the processor is further configured to display on a display coupled to the memory and the processor the plurality of testing elements via a user interface, receive approval of the plurality of testing elements via the user interface, and in response to the received approval, generate the test case comprise the plurality of testing elements.

3. The apparatus of claim **1**, wherein the processor is further configured to generate and output a prompt on a user interface of the user device and receive a response to the prompt from the user interface of the user device.

4. The apparatus of claim **3**, wherein the processor is further configured to generate the plurality of testing elements for the test case based on execution of the GenAI model on the prompt and the response to the prompt.

5. The apparatus of claim **1**, wherein the processor is further configured to generate a description of a plurality actions to be performed by a user during performance of the test case, and store the description of the plurality actions within a document in the memory.

6. The apparatus of claim **1**, wherein the test case comprises perquisites, an objective, references, and test steps that are generated by the GenAI model based on execution of the GenAI model on the descriptions of the requirements of the software program and the repository of test cases.

7. The apparatus of claim **1**, wherein the processor is further configured to display the test case generated by the GenAI model on the user interface, and receive feedback about the test case via the user interface.

8. The apparatus of claim **7**, wherein the processor is further configured to train the GenAI model based on execution of the GenAI model on the test case and the received feedback about the test case.

9. A method comprising:

receiving a request to test a software program from a user device, the request comprising a description of requirements of the software program;

generating a plurality of testing elements based on execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases;

generating a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model; and

storing the test case within a storage device.

10. The method of claim **9**, wherein the method further comprises displaying the plurality of testing elements via a user interface, receiving approval of the plurality of testing elements via the user interface, and in response to the received approval, generating the test case comprise the plurality of testing elements.

11. The method of claim **9**, wherein the method further comprises generating and outputting a prompt on a user interface of the user device and receiving a response to the prompt from the user interface of the user device.

12. The method of claim **11**, wherein the method further comprises generating the plurality of testing elements for the test case based on execution of the GenAI model on the prompt and the response to the prompt.

13. The method of claim **9**, wherein the generating the plurality of test steps comprises generating a description of a plurality actions to be performed by a user during performance of the test case, and the generating the test case comprises storing the description of the plurality of actions within a document.

14. The method of claim **9**, wherein the test case comprises perquisites, an objective, references, and test steps that are generated by the GenAI model based on execution of the GenAI model on the descriptions of the requirements of the software program and the repository of test cases.

15. The method of claim **9**, wherein the method further comprises displaying the test case generated by the GenAI model on the user interface, and receiving feedback about the test case via the user interface.

16. The method of claim **15**, wherein the method further comprises training the GenAI model based on execution of the GenAI model on the test case and the received feedback about the test case.

17. A computer-readable medium comprising instructions stored therein which when executed by a processor cause a computer to perform:

receiving a request to test a software program from a user device, the request comprising a description of requirements of the software program;

generating a plurality of testing elements based on execution of a generative artificial intelligence (GenAI) model on the description of the requirements of the software program and a repository of test cases;

generating a test case for testing the software program where the test case comprises the plurality of testing elements generated by the GenAI model; and

storing the test case within a storage device.

18. The computer-readable medium of claim **17**, wherein the computer is further configured to perform displaying the plurality of testing elements via a user interface, receiving approval of the plurality of testing elements via the user interface, and in response to the received approval, generating the test case comprise the plurality of testing elements.

19. The computer-readable medium of claim **17**, wherein the computer is further configured to perform generating and outputting a prompt on a user interface of the user device and receiving a response to the prompt from the user interface of the user device.

20. The computer-readable medium of claim **17**, wherein the generating the plurality of test steps comprises generating a description of a plurality actions to be performed by a user during performance of the test case, and the generating the test case comprises storing the description of the plurality of actions within a document.

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