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(54) **STORING LOGICAL UNITS OF PROGRAM CODE GENERATED USING A DYNAMIC PROGRAMMING NOTEBOOK USER INTERFACE**

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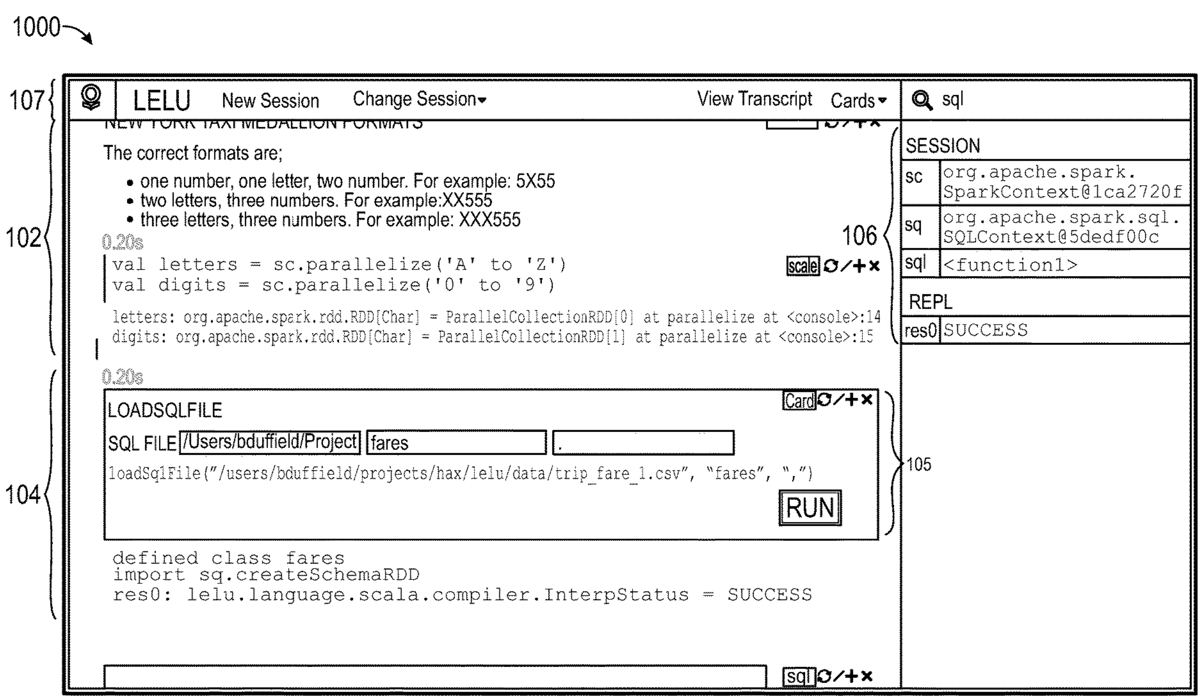
(57) **ABSTRACT**

The programming notebook system, methods, and user interfaces described herein provide software developers with enhanced tools by which a programming notebook workflow and session history associated with code cells in a programming notebook may be tracked and maintained. As a developer progresses through a development workflow, the developer can select an option to save a program code card representing some or all of the program code cell inputs. A card editor user interface may present an aggregated listing of all program code the developer has provided across multiple code cells during the current session which the developer can edit, refine, and/or comment. The card editor may also allow the developer to add associated user interface code to display a UI component associated with the program code card, and allow the developer to add a description and tags for the card so that the card can be searched for and reused.



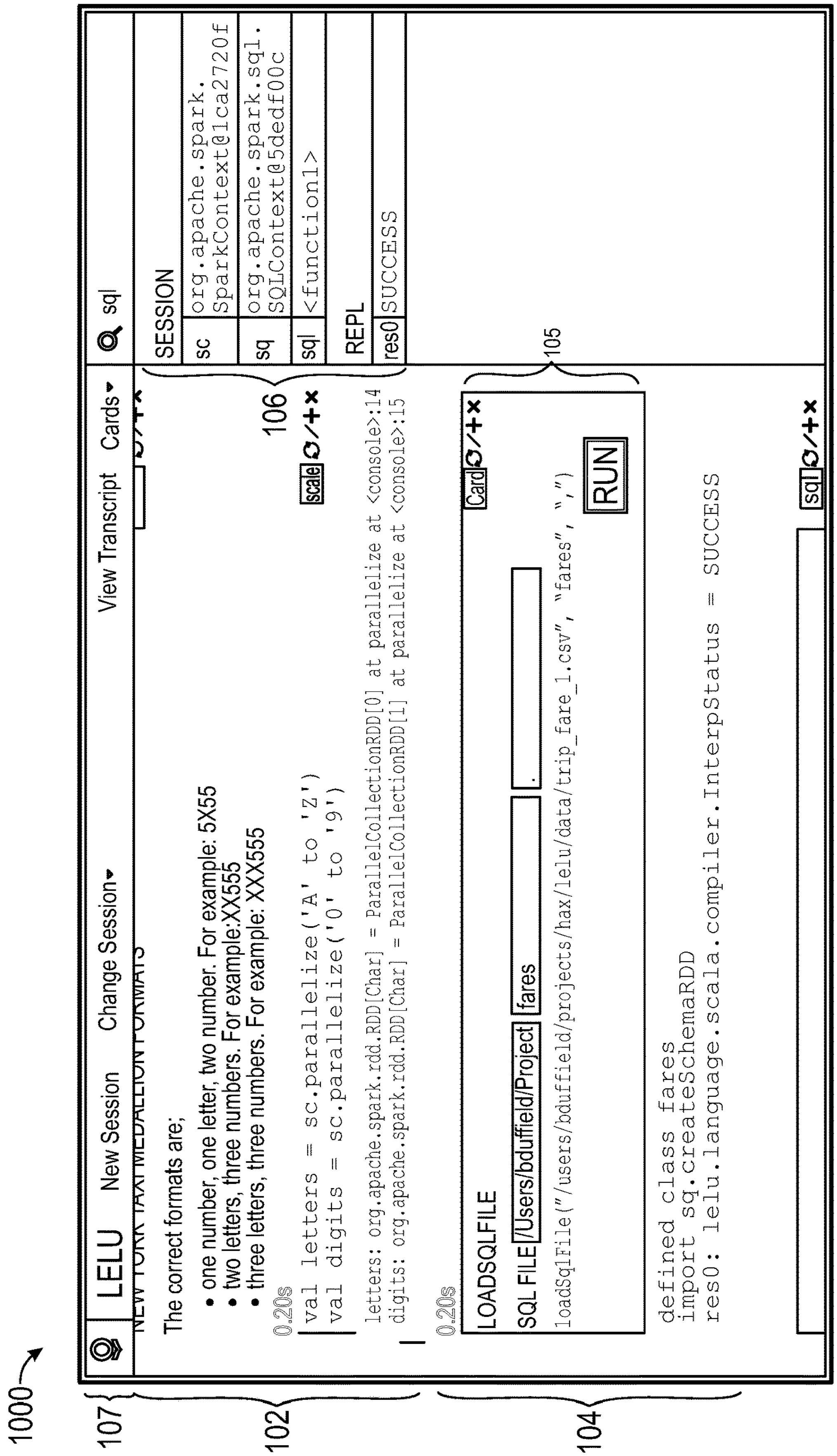

1000
107
102
104
105
106
LELU
New Session
Change Session
View Transcript
Cards
sql
NEW YORK TAXI MEDALLION FORMATS
The correct formats are;
• one number, one letter, two number. For example: 5X55
• two letters, three numbers. For example:XX555
• three letters, three numbers. For example: XXX555
0.20s
val letters = sc.parallelize('A' to 'Z')
val digits = sc.parallelize('0' to '9')
scale
letters: org.apache.spark.rdd.RDD[Char] = ParallelCollectionRDD[0] at parallelize at <console>:14
digits: org.apache.spark.rdd.RDD[Char] = ParallelCollectionRDD[1] at parallelize at <console>:15
0.20s
LOADSQLFILE
Card
SQL FILE /Users/bduffield/Project fares .
loadSqlFile("/users/bduffield/projects/hax/lelu/data/trip_fare_1.csv", "fares", ",")
RUN
defined class fares
import sq.createSchemaRDD
res0: lelu.language.scala.compiler.InterpStatus = SUCCESS
sql
SESSION
sc org.apache.spark.SparkContext@1ca2720f
sq org.apache.spark.sql.SQLContext@5dedf00c
sql <function1>
REPL
res0 SUCCESS

FIG. 1

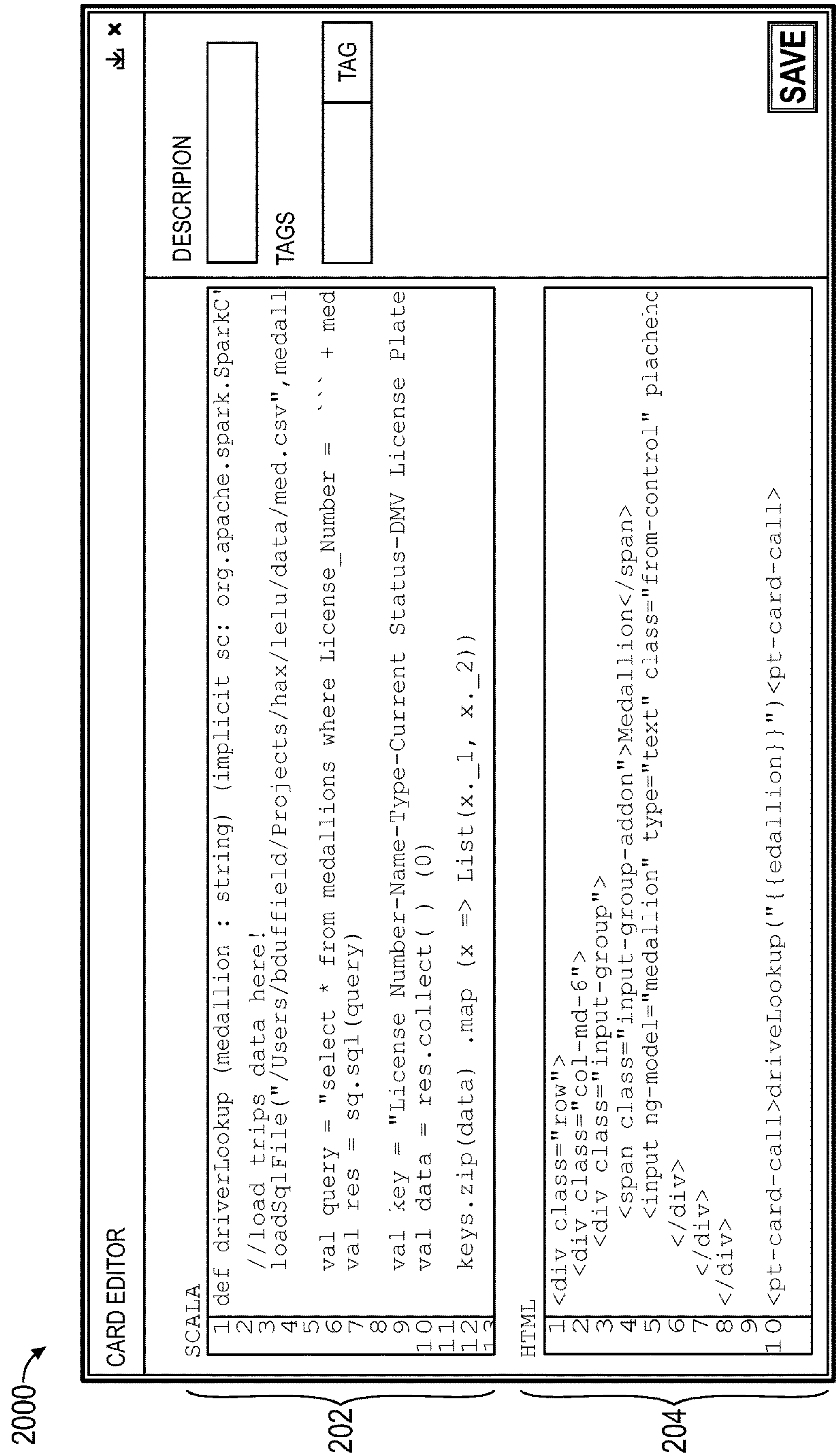

2000
202
204
CARD EDITOR
SCALA
def driverLookup (medallion : string) (implicit sc: org.apache.spark.SparkC'
//load trips data here!
loadSqlFile("/Users/bduffield/Projects/hax/lelu/data/med.csv",medall
val query = "select * from medallions where License_Number = `` + med
val res = sq.sql(query)
val key = "License Number-Name-Type-Current Status-DMV License Plate
val data = res.collect( ) (0)
keys.zip(data) .map (x => List(x._1, x._2))
HTML
<div class="row">
<div class="col-md-6">
<div class="input-group">
Medallion
<input ng-model="medallion" type="text" class="from-control" plachehc
</div>
</div>
</div>
<pt-card-call>driveLookup("{{edallion}}")<pt-card-call>
DESCRIPION
TAGS
TAG
SAVE

FIG. 2

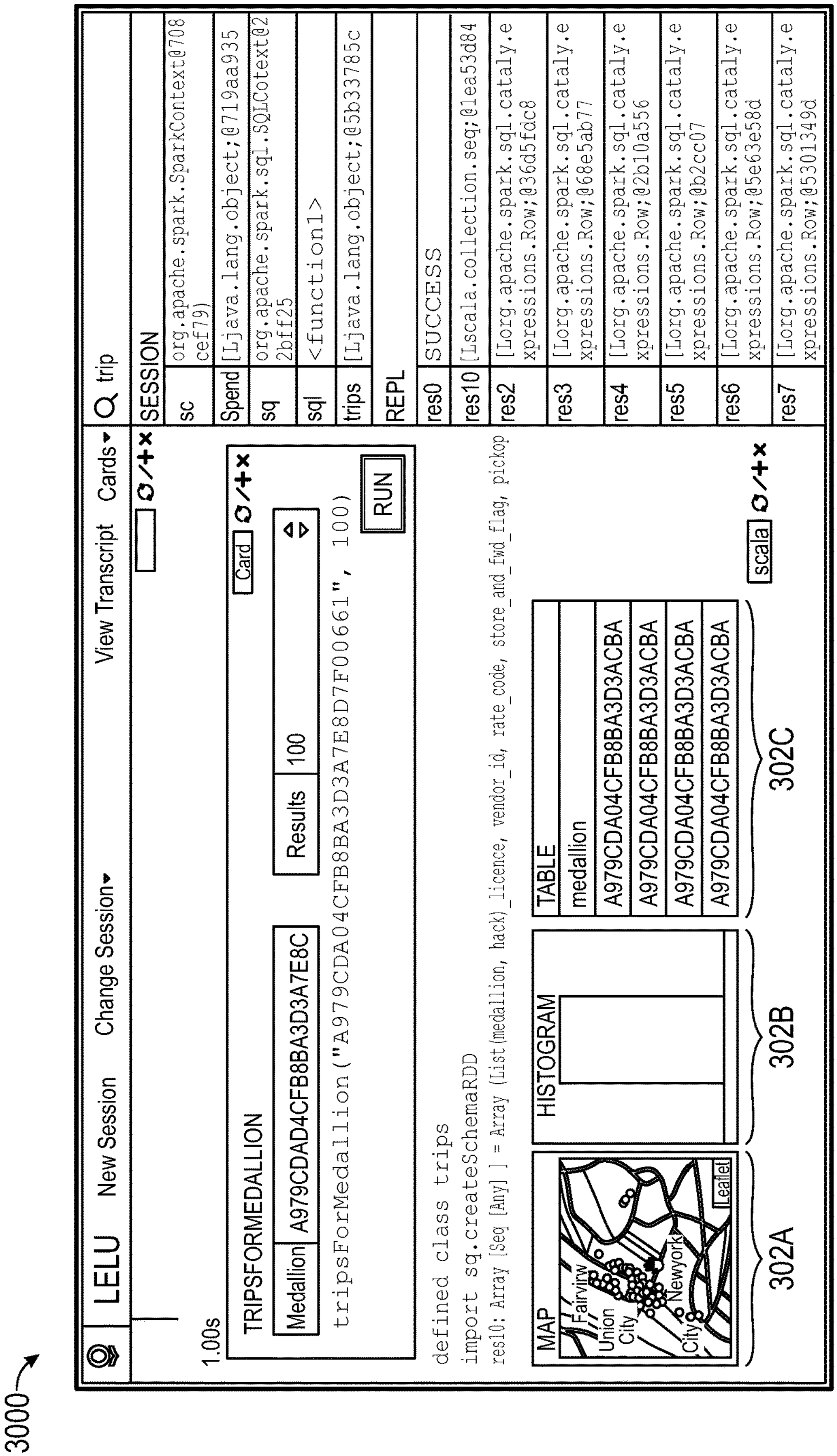

3000
LELU
New Session
Change Session
View Transcript
Cards
trip
1.00s
TRIPSFORMEDALLION
Card
Medallion
A979CDAD4CFB8BA3D3A7E8C
Results
100
tripsForMedallion("A979CDA04CFB8BA3D3A7E8D7F00661", 100)
RUN
defined class trips
import sq.createSchemaRDD
res10: Array [Seq [Any]] = Array (List(medallion, hack) licence, vendor id, rate code, store and fwd flag, pickop
MAP
Fairview
Union City
City
Newyork
Leaflet
HISTOGRAM
TABLE
medallion
A979CDA04CFB8BA3D3ACBA
A979CDA04CFB8BA3D3ACBA
A979CDA04CFB8BA3D3ACBA
A979CDA04CFB8BA3D3ACBA
scala
302A
302B
302C
SESSION
sc
org.apache.spark.SparkContext@708cef79)
Spend
[Ljava.lang.object;@719aa935
sq
org.apache.spark.sql.SQLCotext@22bff25
sql
<function1>
trips
[Ljava.lang.object;@5b33785c
REPL
res0
SUCCESS
res10
[Lscala.collection.seq;@1ea53d84
res2
[Lorg.apache.spark.sql.cataly.expressions.Row;@36d5fdc8
res3
[Lorg.apache.spark.sql.cataly.expressions.Row;@68e5ab77
res4
[Lorg.apache.spark.sql.cataly.expressions.Row;@2b10a556
res5
[Lorg.apache.spark.sql.cataly.expressions.Row;@b2cc07
res6
[Lorg.apache.spark.sql.cataly.expressions.Row;@5e63e58d
res7
[Lorg.apache.spark.sql.cataly.expressions.Row;@5301349d

FIG. 3

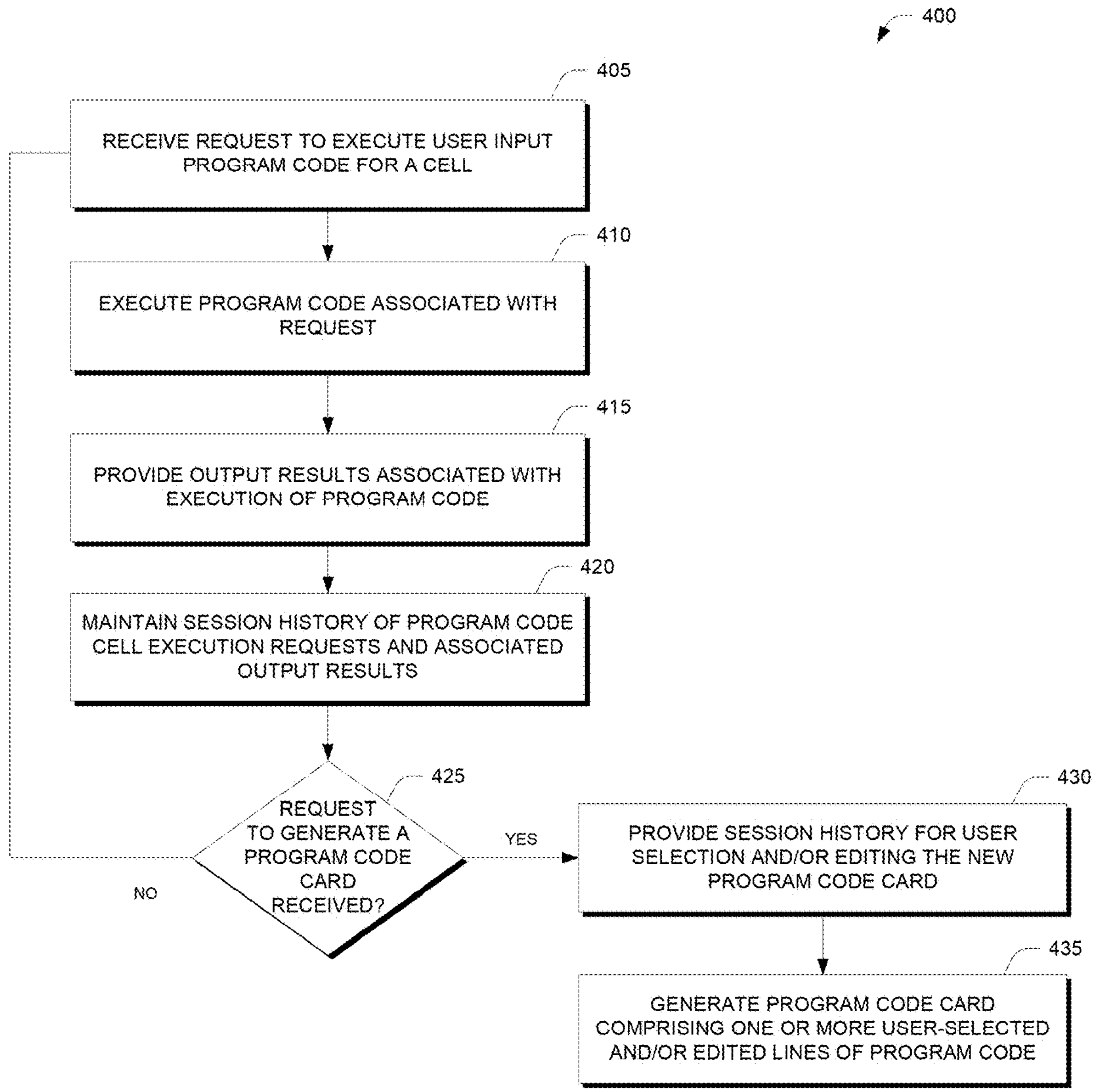

400
405
RECEIVE REQUEST TO EXECUTE USER INPUT PROGRAM CODE FOR A CELL
410
EXECUTE PROGRAM CODE ASSOCIATED WITH REQUEST
415
PROVIDE OUTPUT RESULTS ASSOCIATED WITH EXECUTION OF PROGRAM CODE
420
MAINTAIN SESSION HISTORY OF PROGRAM CODE CELL EXECUTION REQUESTS AND ASSOCIATED OUTPUT RESULTS
425
REQUEST TO GENERATE A PROGRAM CODE CARD RECEIVED?
NO
YES
430
PROVIDE SESSION HISTORY FOR USER SELECTION AND/OR EDITING THE NEW PROGRAM CODE CARD
435
GENERATE PROGRAM CODE CARD COMPRISING ONE OR MORE USER-SELECTED AND/OR EDITED LINES OF PROGRAM CODE

FIG. 4

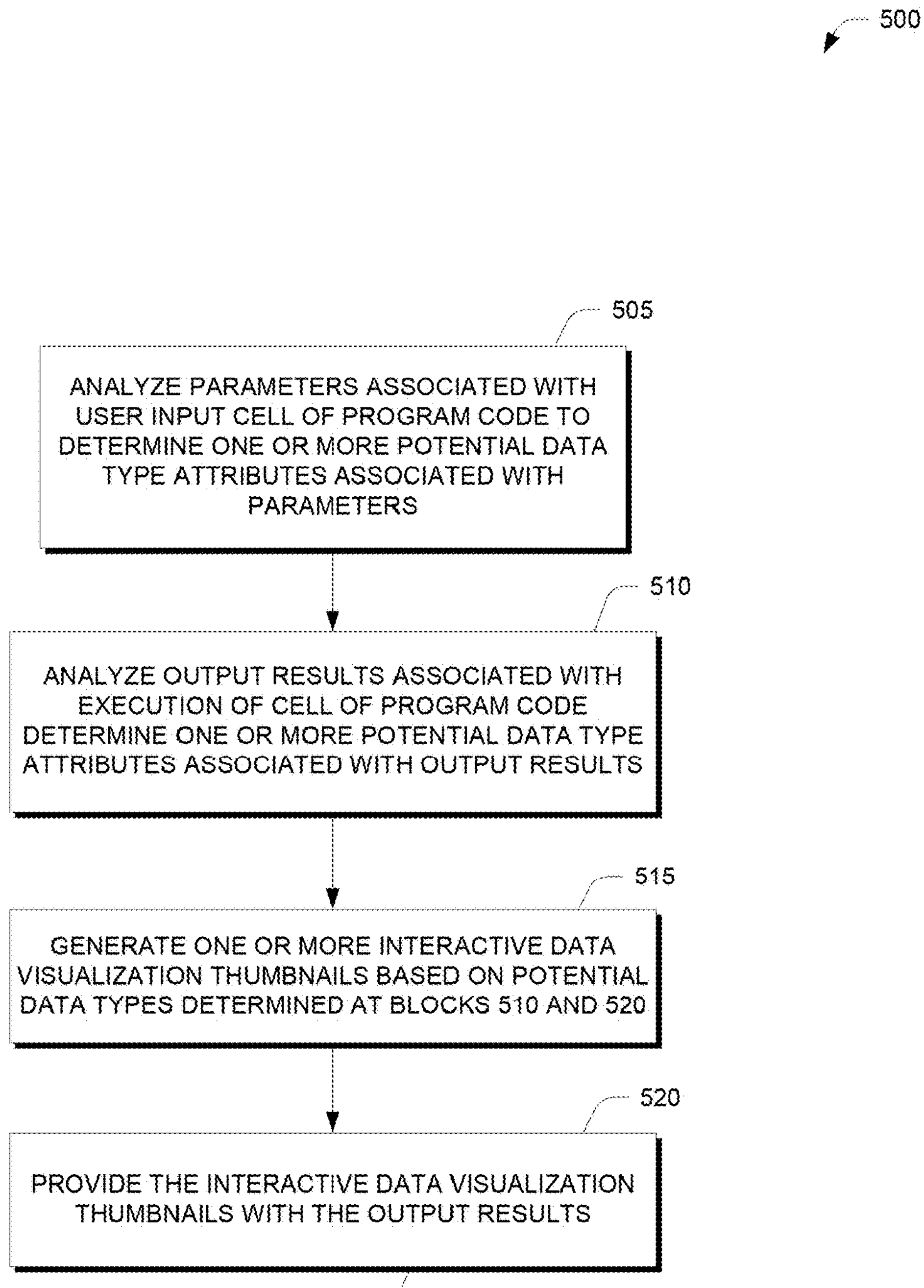

500
505
ANALYZE PARAMETERS ASSOCIATED WITH USER INPUT CELL OF PROGRAM CODE TO DETERMINE ONE OR MORE POTENTIAL DATA TYPE ATTRIBUTES ASSOCIATED WITH PARAMETERS
510
ANALYZE OUTPUT RESULTS ASSOCIATED WITH EXECUTION OF CELL OF PROGRAM CODE DETERMINE ONE OR MORE POTENTIAL DATA TYPE ATTRIBUTES ASSOCIATED WITH OUTPUT RESULTS
515
GENERATE ONE OR MORE INTERACTIVE DATA VISUALIZATION THUMBNAILS BASED ON POTENTIAL DATA TYPES DETERMINED AT BLOCKS 510 AND 520
520
PROVIDE THE INTERACTIVE DATA VISUALIZATION THUMBNAILS WITH THE OUTPUT RESULTS

FIG. 5

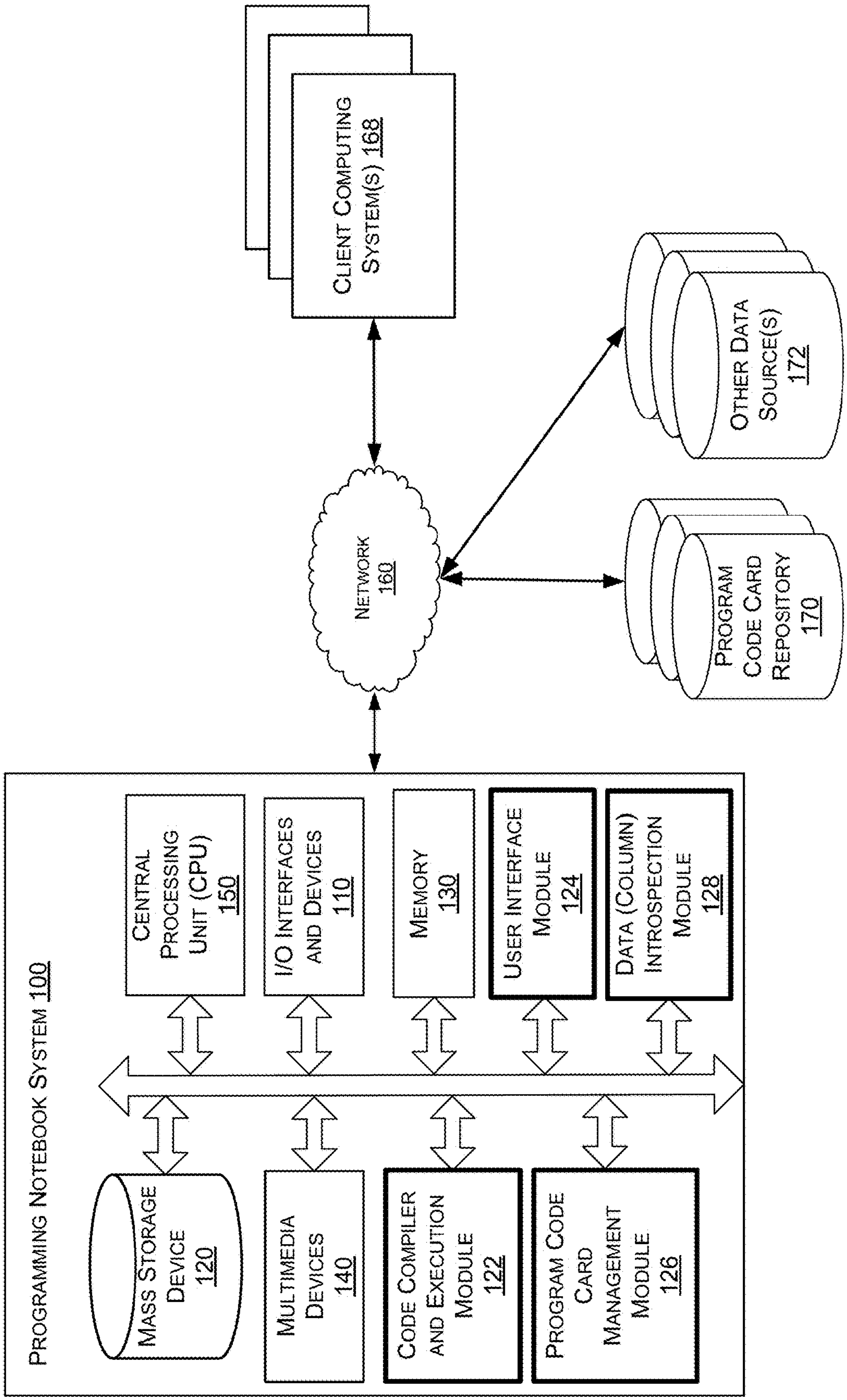

PROGRAMMING NOTEBOOK SYSTEM 100
MASS STORAGE DEVICE 120
MULTIMEDIA DEVICES 140
CODE COMPILER AND EXECUTION MODULE 122
PROGRAM CODE CARD MANAGEMENT MODULE 126
CENTRAL PROCESSING UNIT (CPU) 150
I/O INTERFACES AND DEVICES 110
MEMORY 130
USER INTERFACE MODULE 124
DATA (COLUMN) INTROSPECTION MODULE 128
NETWORK 160
CLIENT COMPUTING SYSTEM(S) 168
PROGRAM CODE CARD REPOSITORY 170
OTHER DATA SOURCE(S) 172

FIG. 6

STORING LOGICAL UNITS OF PROGRAM CODE GENERATED USING A DYNAMIC PROGRAMMING NOTEBOOK USER INTERFACE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 17/070,207, filed Oct. 14, 2020, which is a continuation of U.S. patent application Ser. No. 16/135,285, filed on Sep. 19, 2018, which is a continuation of U.S. patent application Ser. No. 15/392,168, filed on Dec. 28, 2016, which is a continuation of U.S. patent application Ser. No. 14/845,001, filed on Sep. 3, 2015, which claims priority from provisional U.S. Patent Application No. 62/097,388, filed on Dec. 29, 2014. The entire disclosure of each of the above items is hereby made part of this specification as if set forth fully herein and incorporated by reference for all purposes, for all that it contains.

[0002] Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57.

BACKGROUND

[0003] Programming notebooks have become a valuable asset in a software developer's toolkit. A programming notebook, such as the popular iPython Notebook, allows a developer to more rapidly develop and test code, typically by enabling a dynamic command-line shell interface which the developer can use to input, execute, and view associated outputs for lines of program code in a read-execute-print loop ("REPL"). Programming notebook outputs can be provided in various formats, such as a JavaScript Object Notation ("JSON," which is a lightweight data-interchange format) document containing an ordered list of input/output cells which can contain code, text, mathematics, plots and rich media. Programming notebook outputs can also be converted to a number of open standard output formats (HTML, HTML presentation slides, LaTeX, PDF, ReStructuredText, Markdown, Python, etc.).

[0004] Typically, a programming notebook consists of a sequence of cells. A cell is a multi-line text input field, and its contents can be executed by the developer using the programming notebook interface. Code cells allow the developer to edit and write code and can provide features such as syntax highlighting and tab completion. When a cell is executed using a backend system associated with the programming notebook, results are displayed in the notebook as the cell's output. Output can be displayed in a variety of formats such as text, data plots, and tables.

[0005] In a normal programming notebook workflow, the developer can edit cells in-place multiple times until a desired output or result is obtained, rather than having to re-run separate scripts. The programming notebook interface enables the developer to work on complex computational programs in discrete and manageable pieces. The developer can organize related programming ideas into cells and work progressively forward as various pieces are working correctly. Once a developer has completed a workflow, the programming notebook can be saved or downloaded into a format which, among other things, may remove output results and convert some cell contents (e.g., some contents may be converted to non-executable comments in an output programming language).

SUMMARY

[0006] One embodiment comprises a computing system for providing a programming notebook, the computing system comprising: one or more hardware computer processors configured to execute software code; a non-transitory storage medium storing software modules configured for execution by the one or more hardware computer processors. The software modules may comprise at least: a code compiler and execution module configured to: receive, on behalf of a user interacting with a programming notebook user interface in a programming session, a request to execute a unit of program code associated with a program cell in the programming notebook user interface, wherein the unit of program code comprises one or more lines of program code; execute, on behalf of the user, the unit of program code; provide an output result associated with the execution of the unit of program code, wherein the output result is configured for display in association with the program cell in the programming notebook user interface; and a program code card management module configured to: maintain a session history of requests to execute units of program code and associated output results; receive a request to generate a program code card for the programming session; provide a program code card editor user interface including at least an aggregate listing of the lines associated with respective units of program code associated with the session history; receive, via the program code card editor user interface, user input comprising a selection of program code for the program code card; and generate the program code card based at least in part on the user input.

[0007] In another embodiment, the user input further comprises at least some user interface code. In another embodiment, the user input further comprises at least a description or a tag for the program code card. In another embodiment, providing the output result associated with the execution of the unit of program code comprises: analyzing the output result to determine a data type associated with the data type; selecting a data visualization user interface component to include with the output result based at least in part on the data type; generating, based on the output result, a data visualization user interface component; and provide the data visualization user interface component with the output result. In another embodiment, the data visualization user interface component is one of a time series, a scatter plot, a histogram, a chart, a bar graph, or a table. In another embodiment, based on a determination that the data type is a date the data visualization user interface component is a time series. In another embodiment, based on a determination that the data type is a geographic unit of measurement, the data visualization user interface component is a map.

[0008] Another embodiment comprises a computer-implemented method comprising: under control of a hardware computing device configured with specific computer executable instructions: maintaining a session history of requests to execute units of program code received in association with a programming notebook user interface in a programming session, wherein respective units of program code are associated with respective program cells in the programming notebook user interface; receiving a request to generate a program code card for the programming session; providing

a program code card editor user interface including at least an aggregate listing of the units of program code associated with the session history, wherein the aggregate listing includes, for each unit of program code, an indicator label of the associated program cell in the programming notebook user interface; receiving, via the program code card editor user interface, user input comprising a selection of program code for the program code card; and generating the program code card based at least in part on the user input.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** illustrates an example programming workflow user interface for a programming notebook including a program code card component, as generated using one embodiment of the programming notebook system of FIG. **6**.

[0010] FIG. **2** illustrates an example card editor user interface for a programming notebook, as generated using one embodiment of the programming notebook system of FIG. **6**.

[0011] FIG. **3** illustrates an example programming workflow user interface for a programming notebook including one or more automatically generated data visualizations, as generated using one embodiment of the programming notebook system of FIG. **6**.

[0012] FIG. **4** is a flowchart for one embodiment of an example process for generating and storing logical units of program code using a dynamic programming notebook user interface, as used in one embodiment of the programming notebook system of FIG. **6**.

[0013] FIG. **5** is a flowchart for one embodiment of an example process for automatically determining one or more data visualizations to provide with output results generated in response to a program code execution request, as used in one embodiment of the programming notebook system of FIG. **6**.

[0014] FIG. **6** is a block diagram of an implementation of an illustrative programming notebook system.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Overview

[0015] One drawback to existing programming notebook user interfaces and workflows is that the final output tends to be static, susceptible to inadvertent edits and difficult to reverse format corruption if manually edited, and generally does not lend itself well to facilitating re-use, re-execution, or sharing of code developed using the programming notebook interface. For example, using traditional programming notebook user interfaces a developer, in order to re-use code or logic a developer is often required to resort to copying-and-pasting blocks of program logic or code from one notebook to another. As a result, if a bug in the program logic or code is identified, it may only be fixed once in the location it is found; the other "copy" would not be automatically updated, and in many cases the developer that identified and fixed the bug may be unaware that a copy in another notebook may also need to be fixed or updated accordingly. It may never be clear which version of the program logic or code is the "canonical" or master version, and the developer may not even know that other copies of the program logic or code exist in one or more other notebooks.

[0016] As another example of how traditional programming notebook user interfaces are deficient relates to reordering or deleting of cells of program logic in the notebook. Using these functions, a developer may perform some logic development and analysis, and then reorder or delete cells in the analysis workflow such that the notebook may become inconsistent, and in some cases may no longer be "run" from top to bottom because the logic has become inconsistent, invalid, or even corrupt. Other programming environments which utilize or support a REPL-type interface and copying/pasting of code logic may suffer similar failings.

[0017] The programming notebook system, methods, and user interfaces described in this disclosure provide the developer with an enhanced tool by which the workflow and session history associated with code cells in a programming notebook are tracked and maintained. As the developer progresses through a development workflow, when desired outcome results are achieved, the developer can select an option to save a program code card representing some or all of the code cell inputs. A card editor user interface may provide the developer with a code editor input panel which presents an aggregated listing of all program code the developer has provided across multiple code cells during the current session. The developer can edit, refine, comment, and/or otherwise clean-up the aggregated code listing, such as by removing intermediate lines of code which were rendered unnecessary by other lines of code, editing code to refine definitions, adding comments to document the code and what it does, and so on. The card editor may also allow the developer to add associated user interface code to display a UI component associated with the program code card. The card editor may also allow the developer to add a description and tags for the card so that the card can be searched for and reused by other developers using the programming notebook system.

[0018] Once a program code card has been generated and stored by the programming notebook system it is added to a searchable card library. Developers can then search for and add cards to their own programming notebook workflows and leverage the work done by other developers. Cards may be used within a cell in the workflow, for example directly as a call to a function defined by the card or by interaction with an associated UI component defined by the card. For example, a UI component may expose one or more text input boxes corresponding to input parameters for a function defined by the card.

[0019] One potential benefit of enabling re-use of cards in the workflow is that cards can be built on top of each other and saved into new cards, which include or reference program code defined in previous cards. Then, an end user can request to import a program code card into a programming session or workflow. The programming notebook system then imports the program code card into the programming session or workflow, such that the end user can execute, by providing user input to the programming notebook user interface, a unit of program code associated with the program code card.

[0020] Another feature provided by the programming notebook system described herein is enhanced output results which are provided based on introspection of the output results. For example, additional output results may be suggested based on data attributes associated with the output results and/or input parameters. Additional output results might include one or more interactive data visualization thumbnail images and UI controls presenting the output results, or a portion thereof, in various different formats (e.g., a time series, a histogram, a table, a heat map, etc.). Whether and which data visualization thumbnail images and UI controls are displayed may be based on the attributes and/or values of the data output. For example, if data attributes or values indicate the data includes map coordinates, a geographic map data visualization thumbnail image and UI control may be displayed. Or, in another example, if data attributes or values indicate the data includes dates and times, a time series data visualization thumbnail image and UI control may be displayed. Each interactive data visualization thumbnail image and UI control may be generated based on the actual output results be fully interactive such that, for example, if the developer selects the thumbnail a corresponding full or larger size data visualization may be displayed in the programming notebook user interface. Among other benefits this proactive prediction of data visualizations which may be relevant or useful to the developer can help streamline and improve the developer's workflow. For example, being able to quickly review output results can aid the developer in determining whether the program code used to generate the output results may need to be modified and in what ways in order to move closer to or achieve a desired result.

[0021] In one example, an introspection algorithm may be implemented as follows. A visualization may define a set of rules defining what the visualization requires of the underlying data. For example, for a heat map, the rules may specify that (1) the data must be in a tabular format, and (2) the table of data must contain two numeric columns, which are in correct, specified ranges for latitude and longitude (e.g., from negative 90 to positive 90 degrees, from negative 180 to positive 180 degrees). Or, as another example, for a line chart, the rules may specify that, in order to correctly plot a line, (1) if the data is a list of scalars, then the data must contain a set of numbers, or (2) if the data is a list of pairs, then the value of the first coordinate of each pair must be increasing over the list of pairs. Or, as yet another example, for a timeseries plot (e.g., one or more line charts overlaid with a time axis), the rules may specify that (1) the data must be in a tabular format and (2) one column in the table must be in a date-time format or parseable to a date-time format (e.g., an ISO 8601 date format). The rules for each data visualization may then be responsible for providing the data in a normalized form (e.g., for a timeseries, explicit ticks for values on the time axis may be specified). In addition, the rules may be "fuzzy" such that data can be matched to the rules (or the data may satisfy the criteria specified by the rules) in differing degrees. The visualizations may then be ranked based on the degree of match between the data and the rules. (For example, for a heat map, if the names of the columns identified in the table as providing latitude and longitude contain the substrings "lat" or "lon" then this may increase the confidence that a heat map is a valid visualization). The foregoing provides but one example of an introspection algorithm; other approaches may also be used, including various machine learning algorithms which may, for example, be implemented to train or learn over time which particular thumbnail a user actually picks.

[0022] Embodiments of the disclosure will now be described with reference to the accompanying figures, wherein like numerals refer to like elements throughout. The terminology used in the description presented herein is not intended to be interpreted in any limited or restrictive manner, simply because it is being utilized in conjunction with a detailed description of certain specific embodiments of the disclosure. Furthermore, embodiments of the disclosure may include several novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the embodiments of the disclosure herein described.

[0023] For purposes of this disclosure, certain aspects, advantages, and novel features of various embodiments are described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment of the invention. Thus, for example, those skilled in the art will recognize that one embodiment may be carried out in a manner that achieves one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

Example User Interfaces

[0024] FIGS. **1**, **2**, and **3** illustrate example programming notebook user interfaces, as used in one or more embodiments of the programming notebook system **100** of FIG. **6**. The sample user interfaces may be displayed, for example, via a web browser (e.g., as a web page), a mobile application, or a standalone application. However, in some embodiments, the sample user interfaces shown in FIGS. **1**, **2**, and **3** may also be displayed on any suitable computer device, such as a cell/smart phone, tablet, wearable computing device, portable/mobile computing device, desktop, laptop, or personal computer, and are not limited to the samples as described herein. The user interfaces include examples of only certain features that a programming notebook system may provide. In other embodiments, additional features may be provided, and they may be provided using various different user interfaces and software code. Depending on the embodiment, the user interfaces and functionality described with reference to FIGS. **1**, **2**, and **3** may be provided by software executing on the individual's computing device, by a programming notebook system located remotely that is in communication with the computing device via one or more networks, and/or some combination of software executing on the computing device and the programming notebook system. In other embodiments, analogous interfaces may be presented using audio or other forms of communication. In an embodiment, the interfaces shown in FIGS. **1**, **2**, and **3** are configured to be interactive and respond to various user interactions. Such user interactions may include clicks with a mouse, typing with a keyboard, touches and/or gestures on a touch screen, voice commands, physical gestures made within a proximity of a user interface, and/or the like.

[0025] FIG. **1** (split across illustrates an example programming workflow user interface **1000** for a programming notebook including a program code card component, as generated using one embodiment of the programming notebook system of FIG. **6**. The programming workflow user interface **1000** may be displayed in association with a programming session and enable a developer to quickly and interactively compose and execute lines of program code and view associated output results.

[0026] The programming workflow user interface **1000** of FIG. **1** includes several illustrative program cells. Program cell **102** includes two lines of program code and respective printouts of results from execution of the two lines of program code. Each program cell may also include, for example, an execution time status indicator to indicate how long the program code took to execute. Each program cell may also include a submenu of available actions with respect to the program cell, which may include for example a label descriptor to describe a type of code or mode associated with the program cell (e.g., a programming language indicator such as "Scala," "python," "HTML," "JavaScript," "markdown," "sql," and so on; a card mode indicator to indicate that the program cell is being used to display or invoke a card; and other similar types of modes). The program cell submenu may also include an option to execute the program code in the cell, an option to edit the cell (e.g., the developer may return to a previous cell, edit the program cell contents, and re-run the program cell to produce updated output results); an option to expand the size of the input box (e.g., if the developer wishes to add more lines of code than available space allows); and an option to delete, remove, or otherwise discard the program cell from the current session.

[0027] Program cell **104** represents a program code card which has been added to the current session and invoked by the developer to call a particular function defined by the logic in the program code card. In this example the card in program cell **104** has an associated UI control **105**, which may optionally be specified by a user when the card is created or edited. For example, the card included at program cell **104** displays a function label; three text input boxes for the input parameters used by the function; and a function call preview displaying the function to be called with the provided input parameters (e.g., "cardFunction(input1,input2)") when the program cell is executed. The UI control **105** for the card at program cell **104** also includes a "Run" button which the developer can select in order to run the card's program code. In some embodiments more advanced UI controls and inputs may be provided for the card, as specified by the developer using the card editor user interface (such as the one shown in FIG. **2**). In other embodiments, no UI control **105** may be provided and the developer using the card may type the function call and input parameters (e.g., "card.cardFunction(input1,input2)") directly into the default text box provided by the program cell.

[0028] The programming workflow user interface **1000** may include a main menu **107** providing additional features for the programming notebook. For example, the programming notebook system **100** may support or enable the developer to launch multiple sessions and switch between them. Thus, a "new session" option may cause the programming notebook system **100** to display a clean copy of the programming workflow user interface **1000** (e.g., including one empty program cell for the developer to begin a new session workflow). Additionally, a "change session" option may allow the developer to switch between multiple active sessions. User selection of this option may cause the programming notebook system **100** to display a copy of the programming workflow user interface **1000** for the changed-to session (e.g., including any program cell(s) and result outputs associated with the changed-to session for the developer to continue the changed-to session workflow).

[0029] The main menu **107** in FIG. **1** may also include a transcript option for the developer to view a transcript of program code for the current session. The transcript can include an aggregate listing of the lines of program code input by the developer across all program cells for the current session, without the result outputs associated with each program cell. The transcript may be generated to automatically insert program cell identifiers as code comments to identify or delimit the contents of each respective program cell (e.g., "// cell 1," "//cell 2," etc.). In certain embodiments in which the developer has imported a program code card in the programming workflow user interface, the transcript view may be generated to include (1) the function or code used to invoke the underlying code associated with the card, (2) the underlying code, and/or (3) an option to toggle or switch between (1) and (2).

[0030] As the developer progresses through a workflow and the number of program cells used in the current session increases, the transcript may be updated to reflect the current session. If a developer returns to or re-uses a program cell, the program cell identifiers may indicate this in some manner, such as with a revised identification, timestamp, or other way. For instance, a revised and/or re-executed program cell may be added as a new cell in the session history and associated transcript.

[0031] The main menu in FIG. **1** may also include a card menu option for the developer to create a new card from program code used in the current session, and/or to search for and add cards from a library of cards which have been created by the developer and/or other developers using the programming notebook system of FIG. **6**. An example card editor user interface is illustrated and described in more detail with reference to FIG. **2**. Saved cards may be stored, searched, and accessed, for example, from the program code card repository **122**. Cards may be searched based on a name, a description, and/or one or more tags, as well as other searchable attributes (including in some cases the underlying code associated with the card) provided by the developer when the card is created or edited.

[0032] The programming workflow user interface **1000** may also include a session UI panel **106** which lists, for the current session, variables and their current values and/or functions which have been defined. For example, the session panel **106** listing includes, among other things, variables for "sc" and "sq" and a sql function "<function1>." The programming workflow user interface **1000** may also include a REPL UI panel which lists a summary of result outputs for the current session. The session panel and the REPL UI panels provide the developer with useful at-a-glance information to aid the developer's workflow and code refinement process.

[0033] FIG. **2** illustrates an example card editor user interface **2000** for a programming notebook, as generated using one embodiment of the programming notebook system of FIG. **6**. The card editor user interface **2000** may be displayed in response to the developer's selection of an option to create a new card based on the current session. The card editor user interface **2000** may be initialized by the programming notebook system **100** to include program code content associated with the current session in the main programming workflow UI. In particular, the program code may be accessed from the transcript associated with the current session and displayed in a first user-editable text area **202** by which the developer can edit the program code (e.g., add or remove lines, insert code comments and specifications, and other general code clean up and maintenance). In one embodiment the entire contents of the current session transcript may be displayed in the card editor for the developer to edit. In another embodiment, the main programming workflow user interface may include user-selectable options for the developer to select one or more program code cells from which to extract program code for the card editor.

[0034] The card editor user interface **2000** may also include a second user-editable text area **204** by which the developer may optionally provide user interface code to be associated with the program code logic of the card. For example, as shown in FIG. **2**, HTML and JavaScript may be input by the developer to generate a web-based UI component for the card. Then, when the card is used in subsequent programming notebook sessions, the programming notebook system **100** can interpret the UI code for the card in order to cause display of the UI component directly within the programming notebook UI (for example, as show in program cell **104** of the programming workflow user interface in FIG. **1**).

[0035] The card editor user interface **2000** also provides options for the developer to provide a description and one or more tags to be associated with the card when it is saved. The description and/or tags may be searchable by other users of the programming notebook system **100** to facilitate re-use of cards across many developer sessions. When the developer is satisfied with the card's settings, a save option may be selected in order to save the card, for example in the program code card repository **170**. After the card is saved, the card editor user interface **3000** may be closed (automatically or manually) and the developer can return to the main programming workflow UI. If the developer desires, one or more program cells (for example, those that were used as inputs to the card) may be removed from the workflow by using the respective delete options. However, in some embodiments, the program cell may not also be removed from the transcript. That is, in some instances, the transcript is implemented as immutable log of everything that happens in the workflow, including deletion events. Thus, deletion of a program cell may be more like hiding, in that the transcript still maintains a copy of the deleted cell. Then, the transcript view could be augmented to show or indicate when an entry in the transcript no longer exists in the main programming workflow UI (e.g., this may be visually indicated to the user via some formatting change, an icon, and so on).

[0036] FIG. **3** illustrates an example programming workflow user interface **3000** for a programming notebook including one or more automatically generated data visualizations, such as example visualizations **302**A, **302**B, and **302**C of FIG. **3**, as generated using one embodiment of the programming notebook system of FIG. **6**. The data visualizations may be of particular benefit to the developer in the context of database queries in order to quickly view query results and assess whether the query needs to be revised or tweaked to improve the quality of the output results. The data visualizations **302** (including **302**A, **302**B, and **302**C) shown in user interface **3000** are user-selectable image thumbnails or miniaturized visualizations of the actual output results. In response to the user selecting one of the data visualizations, a larger corresponding version of the same data may be displayed in the main workflow of the user interface **3000** to enable the developer to explore the output results. A variety of data visualizations, ranging from thumbnail to normal to large sized, may be generated and displayed, including but not limited to time series, histograms, tables, graphics, heat maps, and other types of data charts and visualizations.

[0037] The data visualizations **302** shown in user interface **3000** may be generated, for example, in accordance with the process **500** illustrated and described with reference to FIG. **5** herein. In particular, the data visualizations may be automatically selected for generation and generated based at least in part on an analysis of the type of data returned with the output results. For example, the programming notebook system **100** may analyze the output results, determine that the output results include geographic data (such as latitude and longitude coordinates), and generate a map data visualization, such as visualization **302**A, for display with the output results in the main programming workflow user interface

Examples of Processes Performed by Programming Notebook Systems

[0038] FIGS. **4** and **5** are flowcharts illustrating various embodiments of programming notebook system processes. In some implementations, the processes are performed by embodiments of the programming notebook system **100** described with reference to FIG. **6** and/or by one of its components, such as the such as the code compiler and execution module **122**, the program code card management module **126**, or the data (column) introspection module **128**. For ease of explanation, the following describes the services as performed by the programming notebook system **100**. The example scenarios are intended to illustrate, but not to limit, various aspects of the programming notebook system **100**. In one embodiment, the processes can be dynamic, with some procedures omitted and others added.

Generating Logical Units of Program Code

[0039] FIG. **4** is a flowchart illustrating one embodiment of a process **400** for generating and storing logical units of program code using a dynamic programming notebook user interface, as used in one embodiment of the programming notebook system **100** of FIG. **6**. Depending on the embodiment, the method of FIG. **4** may include fewer or additional blocks and the blocks may be performed in an order that is different than illustrated.

[0040] The process **400** begins at block **405** where the programming notebook system receives a request to execute user input program code for a cell, such as input provided by a developer interacting with the programming workflow user interface **1000**. This aspect of the process may be referred to as the "read" part of a read-eval-print loop (REPL). The request to execute program code may include one or more lines of program code of varying complexity and may include operations such as, but not limited to, initiating a database connection, submitting queries to the database, defining variables and functions, inserting code comments and markup, and so on. The programming notebook system **100** may be configured to support a wide variety of programming languages, including but not limited to Scala, Python, HTML, JavaScript, Ruby, and so on.

[0041] At block **410**, the programming notebook system **100** executes the program code associated with the request. This may be, for example, the "eval" part of REPL. The program code received with the request is evaluated and executed to produce output results. The output results may include a wide range of programmatic outputs including no output (e.g., a simple return), a Boolean value, a variable, a value, search query results, and the like. As discussed further herein, the output results may further include, or be analyzed to include, one or more data visualizations which may be of possible interest to the developer based on any inputs in the program code and/or based on the output results.

[0042] At block **415**, the programming notebook system **100** provides the output results associated with execution of the program code, e.g., as produced at block **410**. This aspect of the process corresponds to the "print" part of the REPL. The output results may be presented or configured for presentation in the programming workflow user interface **1000**, for example below the program cell used by the developer to input the program code for the request.

[0043] At block **420** the programming notebook system **100** maintains the session history of program code cell execution requests and the associated output results. The session history may be maintained and used by the programming notebook system **100** in memory **130** (e.g., for the duration of the current session or as the developer switches between multiple sessions) or stored for later access and retrieval (e.g., in one of the other data sources **174** of FIG. **6**). The session history may be used to, for example, generate a transcript of the current session in response to the user's selection of the view transcript option (see, e.g., FIG. **1**). The session history may be used to generate or initialize a card editor user interface, as further described below.

[0044] At block **425** the programming notebook system **100** determines whether a request to generate a program code card has been received. If such a request has not been received, then the process **400** may return to block **405** and continue processing program code execution requests in the REPL from blocks **405** to **415** as many times as the developer would like.

[0045] In response to a request to generate a program code card has been received, the process may proceed to block **430**. At block **430**, the maintained session history is provided to allow the user to select and/or edit program code for the program code card. For example, the maintained session history may include all program code, organized by respective cells, which the user provides as input for the current session. The program code may be displayed, for example, as a listing of program code in a user-editable text area within a card editor user interface, such as the card editor user interface **2000** of FIG. **2**. As discussed with reference to FIG. **2**, the card editor UI may also enable the user to add additional program code for an associated UI component for the card.

[0046] When the user has completed editing of the program code, associated UI code, description, and/or tags, she can select the "Save" (or similar) option. In response, at block **435**, the programming notebook system **100** generates the program code card comprising one or more user selected and/or edited lines of program code. Once the program card code has been generated the programming notebook system **100** can store the program code card, for example at the program code card repository **170**.

Determining Data Visualizations to Provide with Program Code Output Results

[0047] FIG. **5** is a flowchart illustrating one embodiment of a process **500** for automatically determining one or more data visualizations to provide with output results generated in response to a program code execution request, as used in one embodiment of the programming notebook system **100** of FIG. **6**. Depending on the embodiment, the method of FIG. **5** may include fewer or additional blocks and the blocks may be performed in an order that is different than illustrated.

[0048] The process **500** begins at block **505** where the programming notebook system **100** analyzes parameters associated with the program code provided by the user at a cell in the main programming workflow UI to determine one or more potential data type attributes associated with the input parameters. For example, the program code to be executed might include one or more input parameters of a particular data type which may suggest what type of data the output results will be.

[0049] At block **510**, the programming notebook system **100** analyzes the output results associated with execution of the program code for the cell to determine one or more potential data type attributes associated with the output results. For example, if the output results comprise a table of data (e.g., rows and columns) then the columns and/or data values may be analyzed to identify the type of data associated with each column. For example, if the output results table of data includes column headers, these headers may contain contextual information to indicate the type of data (e.g., a column labeled with the word "DATE" is likely to be a date data attribute, a column labeled with the word "CITY" is likely to be a geographical data attribute, and so on). Further, the output results data table values may be parsed and analyzed to determine probable data types, in particular if no column headings or other metadata is available. For example, values in the format "####-##-##" may be analyzed and interpreted by the programming notebook system **100** to indicate that the value is likely to be a date data attribute. In other examples standard formats may be analyzed and compared to results data to identify probable matches or data types including latitude and longitude coordinates, geographic abbreviations, special symbols which may indicate the data type (e.g., currency symbols).

[0050] At block **515**, the programming notebook system **100** generates one or more interactive data visualization thumbnails based on the potential data types identified at blocks **505** and **510**. The data visualization thumbnails may include one or more of a time series, a histogram, a table, a heat map, a geographic map, a scatter plot, a line graph, a pie chart, or any other type of data visualization. Whether and which data visualization thumbnails are selected may depend on the detected data types (and/or probable data types) and/or combinations of data types. For example, if geographic data types are identified, a geographic map may be generated as one of the data visualizations. Or, if date and time data types are identified, a time series or a calendar may be generated as data visualizations. The data visualizations may be generated based on the actual output results to provide an accurate view of the data.

[0051] At block **520**, the programming notebook system **100** provides the interactive data visualization thumbnails with the output results. The interactive data visualizations may then be displayed with the output results, for example in the programming workflow user interface **3000** above or below the program cell used by the developer to input the program code for the request. The data visualizations may be configured to respond to user interaction by, for example, causing display of a larger non-thumbnail version of the data visualization in the programming workflow user interface **3000**. The larger non-thumbnail version may be fully interactive and support user functionality such as zooming in our out, manipulating parameters, selecting portions of the visualization to filter results, and so on.

Example System Implementation and Architecture

[0052] FIG. **6** is a block diagram of one embodiment of a programming notebook system **100** in communication with a network **160** and various systems, such as client computing systems(s) **168**, program code card repository **170**, and/or other data source(s) **172**. The programming notebook system **100** may be used to implement systems and methods described herein, including, but not limited to the processes **400** of FIG. **4** and the process **500** of FIG. **5**.

Programming Notebook System

[0053] In the embodiment of FIG. **6**, the programming notebook system **100** includes a code compiler and execution module **122**, a program code card management module **126**, a data (column) introspection module **128**, and a user interface module **124** that may be stored in the mass storage device **120** as executable software codes that are executed by the CPU **150**. These and other modules in the programming notebook system **100** may include, by way of example, components, such as software components, object-oriented software components, class components and task components, processes, functions, attributes, procedures, subroutines, segments of program code, drivers, firmware, microcode, circuitry, data, databases, data structures, tables, arrays, and variables. In the embodiment shown in FIG. **6**, the programming notebook system **100** is configured to execute the modules recited above to perform the various methods and/or processes herein (such as the processes described with respect to FIGS. **4** and **5** herein).

[0054] The code compiler and execution module **122** provides capabilities related to execution of program code associated with requests received by the programming notebook system **100**, for example as described by the process **400** of FIG. **4**. The program code card management module **126** provides capabilities related to storing and searching program code cards, some aspects of which are described by the process **400** of FIG. **4** and/or the user interface **1000** of FIG. **1**. The data (column) introspection module **128** provides capabilities related to analyzing inputs and outputs associated with executed program code to automatically identify potential data visualizations which may be of use to the end user, for example as described by the process **500** of FIG. **5**. The user interface module **124** provides capabilities related to generation and presentation of one or more user interfaces, such as the sample user interfaces illustrated with reference to FIGS. **1**, **2**, and **3** herein.

[0055] The programming notebook system **100** includes, for example, a server, workstation, or other computing device. In one embodiment, the exemplary programming notebook system **100** includes one or more central processing units ("CPU") **150**, which may each include a conventional or proprietary microprocessor. The programming notebook system **100** further includes one or more memories **130**, such as random access memory ("RAM") for temporary storage of information, one or more read only memories ("ROM") for permanent storage of information, and one or more mass storage device **120**, such as a hard drive, diskette, solid state drive, or optical media storage device. Typically, the modules of the programming notebook system **100** are connected to the computer using a standard based bus system. In different embodiments, the standard based bus system could be implemented in Peripheral Component Interconnect ("PCI"), Microchannel, Small Computer System Interface ("SCSI"), Industrial Standard Architecture ("ISA"), and Extended ISA ("EISA") architectures, for example. In addition, the functionality provided for in the components and modules of programming notebook system **100** may be combined into fewer components and modules or further separated into additional components and modules.

[0056] The programming notebook system **100** is generally controlled and coordinated by operating system software, such as Windows XP, Windows Vista, Windows **7**, Windows **8**, Windows Server, UNIX, Linux, SunOS, Solaris, iOS, Blackberry OS, or other compatible operating systems. In Macintosh systems, the operating system may be any available operating system, such as MAC OS X. In other embodiments, the programming notebook system **100** may be controlled by a proprietary operating system. Conventional operating systems control and schedule computer processes for execution, perform memory management, provide file system, networking, I/O services, and provide a user interface, such as a graphical user interface ("GUI"), among other things.

[0057] The exemplary programming notebook system **100** may include one or more commonly available input/output (I/O) devices and interfaces **110**, such as a keyboard, mouse, touchpad, and printer. In one embodiment, the I/O devices and interfaces **110** include one or more display devices, such as a monitor, that allows the visual presentation of data to a user. More particularly, a display device provides for the presentation of GUIs, application software data, and multimedia analytics, for example. The programming notebook system **100** may also include one or more multimedia devices **140**, such as speakers, video cards, graphics accelerators, and microphones, for example.

Network

[0058] In the embodiment of FIG. **6**, the I/O devices and interfaces **110** provide a communication interface to various external devices. In the embodiment of FIG. **6**, the programming notebook system **100** is electronically coupled to a network **160**, which comprises one or more of a LAN, WAN, and/or the Internet, for example, via a wired, wireless, or combination of wired and wireless, communication link. The network **160** communicates with various computing devices and/or other electronic devices via wired or wireless communication links.

[0059] According to FIG. **6**, in some embodiments information may be provided to or accessed by the programming notebook system **100** over the network **160** from one or more program code card repository **170** and/or other data source(s) **172**. The program code card repository **170** may store, for example, logical units of program code (e.g., "cards") generated using the methods described herein. The program code card repository **170** and/or other data source (s) **172** may include one or more internal and/or external data sources. In some embodiments, one or more of the databases or data sources may be implemented using a relational database, such as Sybase, Oracle, CodeBase, MySQL, and Microsoft® SQL Server as well as other types of databases such as, for example, a flat file database, an entity-relationship database, and object-oriented database, and/or a record-based database

Other Embodiments

[0060] Each of the processes, methods, and algorithms described in the preceding sections may be embodied in, and fully or partially automated by, code modules executed by one or more computer systems or computer processors comprising computer hardware. The code modules may be stored on any type of non-transitory computer-readable medium or computer storage device, such as hard drives, solid state memory, optical disc, and/or the like. The systems and modules may also be transmitted as generated data signals (for example, as part of a carrier wave or other analog or digital propagated signal) on a variety of computer-readable transmission mediums, including wireless-based and wired/cable-based mediums, and may take a variety of forms (for example, as part of a single or multiplexed analog signal, or as multiple discrete digital packets or frames). The processes and algorithms may be implemented partially or wholly in application-specific circuitry. The results of the disclosed processes and process steps may be stored, persistently or otherwise, in any type of non-transitory computer storage such as, for example, volatile or non-volatile storage.

[0061] In general, the word "module," as used herein, refers to logic embodied in hardware or firmware, or to a collection of software instructions, possibly having entry and exit points, written in a programming language, such as, for example, Java, Lua, C or C++. A software module may be compiled and linked into an executable program, installed in a dynamic link library, or may be written in an interpreted programming language such as, for example, BASIC, Perl, or Python. It will be appreciated that software modules may be callable from other modules or from themselves, and/or may be invoked in response to detected events or interrupts. Software modules configured for execution on computing devices may be provided on a computer readable medium, such as a compact disc, digital video disc, flash drive, or any other tangible medium. Such software code may be stored, partially or fully, on a memory device of the executing computing device, such as the programming notebook system **100**, for execution by the computing device. Software instructions may be embedded in firmware, such as an EPROM. It will be further appreciated that hardware modules may be comprised of connected logic units, such as gates and flip-flops, and/or may be comprised of programmable units, such as programmable gate arrays or processors. The modules described herein are preferably implemented as software modules, but may be represented in hardware or firmware. Generally, the modules described herein refer to logical modules that may be combined with other modules or divided into sub-modules despite their physical organization or storage.

[0062] The various features and processes described above may be used independently of one another, or may be combined in various ways. All possible combinations and subcombinations are intended to fall within the scope of this disclosure. In addition, certain method or process blocks may be omitted in some implementations. The methods and processes described herein are also not limited to any particular sequence, and the blocks or states relating thereto can be performed in other sequences that are appropriate. For example, described blocks or states may be performed in an order other than that specifically disclosed, or multiple blocks or states may be combined in a single block or state. The example blocks or states may be performed in serial, in parallel, or in some other manner. Blocks or states may be added to or removed from the disclosed example embodiments. The example systems and components described herein may be configured differently than described. For example, elements may be added to, removed from, or rearranged compared to the disclosed example embodiments.

[0063] Conditional language used herein, such as, among others, "can," "could," "might," "may," "for example," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment. The terms "comprising," "including," "having," and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations, and so forth. Also, the term "or" is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term "or" means one, some, or all of the elements in the list. Conjunctive language such as the phrase "at least one of X, Y and Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y and at least one of Z to each be present.

[0064] While certain example embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the disclosure. Thus, nothing in the foregoing description is intended to imply that any particular element, feature, characteristic, step, module, or block is necessary or indispensable. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions, and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions disclosed herein. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of certain of the inventions disclosed herein.

[0065] Any process descriptions, elements, or blocks in the flow diagrams described herein and/or depicted in the attached figures should be understood as potentially representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process. Alternate implementations are included within the scope of the embodiments described herein in which elements or functions may be deleted, executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those skilled in the art.

[0066] All of the methods and processes described above may be embodied in, and partially or fully automated via, software code modules executed by one or more general purpose computers. For example, the methods described herein may be performed by the programming notebook system **100** and/or any other suitable computing device. The methods may be executed on the computing devices in response to execution of software instructions or other executable code read from a tangible computer readable medium. A tangible computer readable medium is a data storage device that can store data that is readable by a computer system. Examples of computer readable mediums include read-only memory, random-access memory, other volatile or non-volatile memory devices, CD-ROMs, magnetic tape, flash drives, and optical data storage devices.

[0067] It should be emphasized that many variations and modifications may be made to the above-described embodiments, the elements of which are to be understood as being among other acceptable examples. All such modifications and variations are intended to be included herein within the scope of this disclosure. The foregoing description details certain embodiments of the invention. It will be appreciated, however, that no matter how detailed the foregoing appears in text, the invention can be practiced in many ways. As is also stated above, it should be noted that the use of particular terminology when describing certain features or aspects of the invention should not be taken to imply that the terminology is being re-defined herein to be restricted to including any specific characteristics of the features or aspects of the invention with which that terminology is associated.

What is claimed is:

1. A computer-implemented method comprising:
by one or more hardware computer processors executing computer-readable instructions:
receiving, from a user, one or more requests to execute units of program code as part of a first session, wherein the units of program code each comprise respective one or more lines of program code;
determining respective outputs associated with the requests to execute the units of program code;
maintaining a session history of the first session, the session history comprising the one or more requests to execute the units of program code and the associated outputs;
receiving a request to generate a program code card based on at least a first unit of program code of the units of program code of the session history; and
in response to receiving the request to generate the program code card:
generating the program code card including at least a portion of the one or more lines of program code of the first unit of program code; and
storing the program code card.

2. The computer-implemented method of claim **1** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
further in response to receiving the request to generate the program code card:
providing a program code card editor user interface including at least the one or more lines of program code of the first unit of program code.

3. The computer-implemented method of claim **2** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
receiving, via the program code card editor user interface, and from the user, a selection of the portion of the one or more lines of program code of the first unit of program code.

4. The computer-implemented method of claim **2** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
receiving, via the program code card editor user interface, and from the user, a modification to the portion of the one or more lines of program code of the first unit of program code.

5. The computer-implemented method of claim **2** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
receiving, via the program code card editor user interface, and from the user, at least one of a description or a tag for the program code card.

6. The computer-implemented method of claim **2** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
receiving, via the program code card editor user interface, and from the user, a specification of a user interface component for the program code card, wherein the user interface component is usable to render information associated with the program code card.

7. The computer-implemented method of claim **2** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
receiving, via the program code card editor user interface, and from the user, a specification of one or more input parameters associated with the program code card.

8. The computer-implemented method of claim **1** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
providing a user interface including at least an aggregate listing of the lines of program code associated with the respective units of program code associated with the session history; and
receiving, via the user interface, and from the user, a selection of the first unit of program code or the portion of the one or more lines of program code associated with the first unit of program code.

9. The computer-implemented method of claim **8**, wherein the aggregate listing includes, for each unit of program code, an indicator label of the associated unit of program code.

10. The computer-implemented method of claim **1** further comprising:
by the one or more hardware computer processors executing the computer-readable instructions:
receiving a request to import the program code card into a second session; and

importing the program code card into the second session, such that a second user can cause execution, by providing user input, of the portion of the one or more lines of program code associated with the program code card.

11. The computer-implemented method of claim **10** further comprising:

by the one or more hardware computer processors executing the computer-readable instructions:

receiving one or more input parameters and an instruction to execute the program code card in the second session according to the one or more input parameters.

12. The computer-implemented method of claim **1**, wherein the program code card is stored in a library of a plurality of program code cards.

13. The computer-implemented method of claim **12**, wherein the plurality of program code cards in the library are searchable and/or accessible by a plurality of users.

14. A system comprising:

a computer readable storage medium having program instructions embodied therewith; and

one or more processors configured to execute the program instructions to cause the system to perform the computer-implemented method of claim **1**.

15. A computer program product comprising a computer-readable storage medium having program instructions embodied therewith, the program instructions executable by one or more processors to cause the one or more processors to perform the computer-implemented method of claim **1**.

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