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United States Patent	12386610
Kind Code	B2
Date of Patent	August 12, 2025
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Code modification management using machine learning

Abstract

A method comprises collecting data corresponding to one or more code changes in response to committing of the one or more code changes to a code repository, and formatting the data into at least one data string. The at least one data string is inputted to one or machine learning models. Using the one or machine learning models, a natural language description of the one or more code changes is generated based at least in part on the at least one data string. The method further comprises causing transmission of the natural language description of the one or more code changes to a document repository.

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Appl. No.: 18/139746

Filed: April 26, 2023

Prior Publication Data

Document Identifier	Publication Date
US 20240362017 A1	Oct. 31, 2024

Publication Classification

Int. Cl.: G06F9/44 (20180101); G06F8/71 (20180101); G06F8/73 (20180101)

U.S. Cl.:

CPC **G06F8/71** (20130101); **G06F8/73** (20130101);

Field of Classification Search

USPC: None

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Background/Summary

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FIELD

(2) The field relates generally to information processing systems, and more particularly to management of code modifications in information processing systems.

BACKGROUND

(3) Design documentation includes a collection of documents and resources that cover multiple aspects of a product design. Documentation includes, for example, information about users, product features, project deadlines and implementation details. Design documentation may correspond to low-level design (LLD) and high-level design (HLD) features. Due to product design changes, design documents typically need to be updated.

(4) With conventional approaches, design changes may be missed or misinterpreted so that design documents may not be updated or may be updated incorrectly. In addition, design documentation may be updated in the wrong location that does not pertain to the change and/or does not correspond to the latest documentation.

SUMMARY

(5) Embodiments provide a design documentation management platform in an information processing system.

(6) For example, in one embodiment, a method comprises collecting data corresponding to one or more code changes in response to committing of the one or more code changes to a code repository, and formatting the data into at least one data string. The at least one data string is inputted to one or more machine learning models. Using the one or more machine learning models, a natural language description of the one or more code changes is generated based at least in part on the at least one data string. The method further comprises causing transmission of the natural language description of the one or more code changes to a document repository.

(7) Further illustrative embodiments are provided in the form of a non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to perform the above steps. Still further illustrative embodiments comprise an apparatus with a processor and a memory configured to perform the above steps.

(8) These and other features and advantages of embodiments described herein will become more apparent from the accompanying drawings and the following detailed description.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 depicts an information processing system with a design documentation management platform in an illustrative embodiment.

(2) FIG. 2 depicts an operational flow for design documentation management in response to code changes in an illustrative embodiment.

(3) FIG. 3A depicts an operational flow for code change description generation in an illustrative embodiment.

(4) FIG. 3B depicts an architecture of a transformer in an illustrative embodiment.

(5) FIG. 4 depicts example pseudocode for leveraging Key2Text transformers to generate sentences from a set of input words in an illustrative embodiment.

(6) FIG. 5 depicts example pseudocode for passing words for product attributes as a list of text to a model for sentence generation in an illustrative embodiment.

- (7) FIG. 6 depicts example pseudocode for generating a pre-trained GPT2 transformer model from a transformer pipeline and passing attribute values in concatenated text to generate sentences in an illustrative embodiment.
- (8) FIG. 7 depicts collected data corresponding to code changes in an illustrative embodiment.
- (9) FIG. 8 depicts formatted data corresponding to code changes in an illustrative embodiment.
- (10) FIG. 9 depicts design documentation updated with a generated description of code changes in an illustrative embodiment.
- (11) FIG. 10A depicts collected data corresponding to code changes with highlighted key words in an illustrative embodiment.
- (12) FIG. 10B depicts collected data corresponding to code changes with highlighted key words in an illustrative embodiment.
- (13) FIG. 11 depicts collected data corresponding to code changes with highlighted key words in an illustrative embodiment.
- (14) FIG. 12 depicts a process for design documentation management according to an illustrative embodiment.
- (15) FIGS. 13 and 14 show examples of processing platforms that may be utilized to implement at least a portion of an information processing system according to illustrative embodiments.

DETAILED DESCRIPTION

(16) Illustrative embodiments will be described herein with reference to exemplary information processing systems and associated computers, servers, storage devices and other processing devices. It is to be appreciated, however, that embodiments are not restricted to use with the particular illustrative system and device configurations shown. Accordingly, the term “information processing system” as used herein is intended to be broadly construed, so as to encompass, for example, processing systems comprising cloud computing and storage systems, as well as other types of processing systems comprising various combinations of physical and virtual processing resources. An information processing system may therefore comprise, for example, at least one data center or other type of cloud-based system that includes one or more clouds hosting tenants that access cloud resources. Such systems are considered examples of what are more generally referred to herein as cloud-based computing environments. Some cloud infrastructures are within the exclusive control and management of a given enterprise, and therefore are considered “private clouds.” The term “enterprise” as used herein is intended to be broadly construed, and may comprise, for example, one or more businesses, one or more corporations or any other one or more entities, groups, or organizations. An “entity” as illustratively used herein may be a person or system. On the other hand, cloud infrastructures that are used by multiple enterprises, and not necessarily controlled or managed by any of the multiple enterprises but rather respectively controlled and managed by third-party cloud providers, are typically considered “public clouds.” Enterprises can choose to host their applications or services on private clouds, public clouds, and/or a combination of private and public clouds (hybrid clouds) with a vast array of computing resources attached to or otherwise a part of the infrastructure. Numerous other types of enterprise computing and storage systems are also encompassed by the term “information processing system” as that term is broadly used herein.

(17) As used herein, “real-time” refers to output within strict time constraints. Real-time output can be understood to be instantaneous or on the order of milliseconds or microseconds. Real-time output can occur when the connections with a network are continuous and a user device receives messages without any significant time delay. Of course, it should be understood that depending on the particular temporal nature of the system in which an embodiment is implemented, other appropriate timescales that provide at least contemporaneous performance and output can be achieved.

(18) As used herein, “natural language” is to be broadly construed to refer to any language that has evolved naturally in humans. Non-limiting examples of natural languages include, for example,

English, Spanish, French and Hindi.

(19) As used herein, “natural language processing (NLP)” is to be broadly construed to refer to interactions between computers and human (natural) languages, where computers are able to derive meaning from human or natural language input, and respond to requests and/or commands provided by a human using natural language.

(20) As used herein, “natural language understanding (NLU)” is to be broadly construed to refer to a sub-category of natural language processing in artificial intelligence where natural language input is disassembled and parsed to determine appropriate syntactic and semantic schemes in order to comprehend and use languages. NLU may rely on computational models that draw from linguistics to understand how language works, and comprehend what is being said by a user.

(21) As used herein, “natural language generation (NLG)” is to be broadly construed to refer to a computer process that transforms data into natural language. For example, NLG systems decide how to put concepts into words. NLG can be accomplished by training machine learning models using a corpus of human-written texts.

(22) As used herein, “application programming interface (API)” or “interface” refers to a set of subroutine definitions, protocols, and/or tools for building software. Generally, an API defines communication between software components. APIs permit programmers to write software applications consistent with an operating environment or website. APIs are used to integrate and pass data between applications, and may be implemented on top of other systems.

(23) FIG. 1 shows an information processing system **100** configured in accordance with an illustrative embodiment. The information processing system **100** comprises user devices **102-1**, **102-2**, . . . **102-M** (collectively “user devices **102**”), document repositories **103-1**, **103-2**, . . . **103-S** (collectively “document repositories **103**”) and at least one code repository **105**. The user devices **102**, document repositories **103** and code repository **105** communicate over a network **104** with a design documentation management platform **110**. The variable M and other similar index variables herein such as K, L and S are assumed to be arbitrary positive integers greater than or equal to one.

(24) The user devices **102** can comprise, for example, Internet of Things (IoT) devices, desktop, laptop or tablet computers, mobile telephones, or other types of processing devices capable of communicating with the design documentation management platform **110** over the network **104**. Such devices are examples of what are more generally referred to herein as “processing devices.” Some of these processing devices are also generally referred to herein as “computers.” The user devices **102** may also or alternately comprise virtualized computing resources, such as virtual machines (VMs), containers, etc. The user devices **102** in some embodiments comprise respective computers associated with a particular company, organization or other enterprise.

(25) The terms “customer,” “administrator” or “user” herein are intended to be broadly construed so as to encompass numerous arrangements of human, hardware, software or firmware entities, as well as combinations of such entities. Design documentation management services may be provided for users utilizing one or more machine learning models, although it is to be appreciated that other types of infrastructure arrangements could be used. At least a portion of the available services and functionalities provided by the design documentation management platform **110** in some embodiments may be provided under Function-as-a-Service (“FaaS”), Containers-as-a-Service (“CaaS”) and/or Platform-as-a-Service (“PaaS”) models, including cloud-based FaaS, CaaS and PaaS environments.

(26) Although not explicitly shown in FIG. 1, one or more input-output devices such as keyboards, displays or other types of input-output devices may be used to support one or more user interfaces to the design documentation management platform **110**, as well as to support communication between the design documentation management platform **110** and connected devices (e.g., user devices **102**) and/or other related systems and devices not explicitly shown.

(27) In some embodiments, the user devices **102** are assumed to be associated with repair technicians, system administrators, information technology (IT) managers, software developers,

release management personnel or other authorized personnel configured to access and utilize the design documentation management platform **110**.

(28) The user devices **102** are respectively associated with one or more programmers, subject matter experts (SME) or other technical personnel of, for example, an enterprise, who are involved in the design, development, updating and/or versioning of applications, programs, firmware, software or other forms of programming. As explained in more detail herein, the programmers commit code changes to one or more code repositories **105** using, for example, a software development platform like Gitlab. Once code development is completed, a programmer will commit the changes to a code repository **105** (e.g., Gitlab commit SHA: 45c9428c360aeafa17a0e0e9cf7b12d9cca59990).

(29) As noted herein above, with conventional approaches, software design changes may be missed or misinterpreted, resulting in design documents that are not updated or updated incorrectly. In addition, design documentation may be updated in document repository locations that do not pertain to the code changes and/or do not correspond to the latest documentation.

(30) To address the above-noted technical problems with updating design documentation, the illustrative embodiments provide techniques to automatically update design documents in response to code changes. Advantageously, the embodiments provide a platform that triggers collection of and collects code changes in response to code commits on a software development platform (e.g., Gitlab). The code changes are analyzed using one or more machine learning models to generate a natural language description of the changes, and the description is routed to appropriate design documentation locations (e.g., document repositories **103**), where the design documentation is updated to include the code change descriptions. The embodiments advantageously provide techniques to identify and format code changes into one or more data strings, which are inputted to one or machine models that are configured to leverage NLP, NLU, NLG and other machine learning algorithms to generate the code change descriptions.

(31) The design documentation management platform **110** in the present embodiment is assumed to be accessible to the user devices **102**, document repositories **103**, code repository **105** and vice versa over the network **104**. The network **104** is assumed to comprise a portion of a global computer network such as the Internet, although other types of networks can be part of the network **104**, including a wide area network (WAN), a local area network (LAN), a satellite network, a telephone or cable network, a cellular network, a wireless network such as a WiFi or WiMAX network, or various portions or combinations of these and other types of networks. The network **104** in some embodiments therefore comprises combinations of multiple different types of networks each comprising processing devices configured to communicate using Internet Protocol (IP) or other related communication protocols.

(32) As a more particular example, some embodiments may utilize one or more high-speed local networks in which associated processing devices communicate with one another utilizing Peripheral Component Interconnect express (PCIe) cards of those devices, and networking protocols such as InfiniBand, Gigabit Ethernet or Fibre Channel. Numerous alternative networking arrangements are possible in a given embodiment, as will be appreciated by those skilled in the art.

(33) Referring to FIG. 1, the design documentation management platform **110** includes a code development engine **120**, a content collection engine **130**, a data formatting engine **140**, a description generation engine **150** and a routing engine **160**. The description generation engine **150** includes a machine learning layer **151** comprising description generation and training layers **152** and **153**. The routing engine **160** includes a document repository selection layer **161**, one or more repository interfaces **162** and a location identification layer **163**.

(34) Referring to FIG. 1 and to the operational flow **200** in FIG. 2, in a pre-processing stage, once code development is completed, and a programmer commits the changes to a code repository **105** (e.g., code commit **115**), the code development engine **120** (e.g., continuous integration/continuous deployment (CI/CD) pipeline) will automatically trigger the content collection engine **130** to pull

the code changes as plain text and feed the changes into the data formatting engine **140**. The data formatting engine **140** is configured to remove redundant information and maintain actual code differences and required metadata (e.g., application name, target design document database uniform resource identifier (URI), etc.). The data formatting engine **140** is further configured to construct a data string that can be input to a machine learning model for code change description generation.

(35) For example, collected data **700** corresponding to code changes as collected by the content collection engine **130** is depicted in FIG. 7 and formatted data **800** corresponding to the code changes as formatted by the data formatting engine is depicted in FIG. 8. FIGS. 7 and 8 refer to an operational example where, for a commercial transaction, a rest service is created to provide order details for a given order number. In this example, an application programming interface (API) needs to be enhanced to filter only the orderType="SalesOrder" for a specific region. In this case, a Gitlab API is used to pull raw data (e.g., collected data **700**) from the code repository **105** following the committing of the code changes. The Gitlab API corresponds to the following uniform resource locator (URL): url:

<https://gitlab.dell.com/api/v4/projects/165681/repository/commits/feature/diff>

(36) The collected data **700** comprises the code changes and metadata associated with the code changes. The metadata comprises, for example, identifying information of an application for which the code changes have been made (e.g., application name or other identifier), identifying information of the document repository (e.g., URIs, URLs, macros, annotations, etc.) including the design documentation corresponding to the code changes, and/or identifying information of one or more documents in the document repository corresponding to the code changes.

(37) By removing redundancies from the collected data **700** and determining and maintaining portions of the collected data **700** specifying the code changes, the data formatting engine **140** constructs a data string as shown, for example, in the formatted data **800**. In the formatted data **800**, – denotes removal of code and + denotes the addition of new code. In the non-limiting operational example, 'return orderRepository.findById(id)' is removed and 'public List<Orders> getOrderById(Integer id, String orderType, String region)' is added, resulting in filtering only the orderType="SalesOrder" for a specific region.

(38) Based on the data string input from the data formatting engine **140**, in a computing stage, the description generation engine **150** uses NLP, NLU and NLG machine learning techniques to generate a natural language description of the functionality change caused by the code change. In other words, the description generation engine **150**, more particularly, the description generation layer **152** of the machine learning layer **151**, generates a description of the design changes made in the code as received from the code repository **105**. The description is generated by using highly sophisticated neural networks and NLG techniques. Some approaches for sentence generation that may be used by the machine learning model include, but are not necessarily limited to, recurrent neural networks (RNNs), long short-term memory (LSTM) techniques, etc. In illustrative embodiments, the machine learning model leverages transformers for NLP, NLU and NLG techniques. Some of the types of transformers that can be used by the embodiments, include, but are not necessarily limited to, a Bidirectional Encoder Representations from Transformers (BERT) model, a GPT model and a GPT2/3 model. According to one or more embodiments, the technique starts with a pre-trained transformer which is further trained through the training layer **153** with a customized design data corpus of, for example, an enterprise, to yield accurate sentence generation. Referring back to the operational example of creating a rest service to provide order details for a given order number, a generated description by the description generation engine **150** may recite, for example, "order management service to fetch all the order details based on an order ID for a specific order type and for the specified region."

(39) The embodiments provide techniques for NLG of code change descriptions from data strings received from the data formatting engine **140**. For example, referring to the operational flow **300** in FIG. 3A, when a data string is constructed by the data formatting engine **140**, a request to the

description generation engine **150** is invoked to generate a code change description **155** from the data string **141** for the created product. The description generation engine **150** includes a machine learning (ML) layer **151**, which leverages NLG and is trained with historical data from a program design data corpus **154**. The corpus **154** may originate from, for example, an enterprise or other organization to accurately generate textual descriptions of code changes that may be related to a given enterprise or organization.

(40) The description generation engine **150** generates a code change description **155** from a corresponding data string **141** using highly sophisticated neural networks and NLG techniques. As part of the description generation layer **152**, illustrative embodiments leverage one or more transformers (e.g., transformer **352**). As used herein, a “transformer” is to be broadly construed to refer to a deep learning model that differentially weighs the significance of portions of input data. Similar to RNNs, transformers manage sequential input data. However, transformers do not necessarily process the data in order, and utilize mechanisms which provide context for any position in an input sequence. By identifying context, a transformer does not need to process the beginning of a data sequence before the end of the data sequence, which allows for more parallelization than RNNs to reduce training time. Non-limiting examples of transformer-based neural network machine learning models that may be used by the embodiments are a BERT model, a GPT model and a GPT2/3 model, which may use context from both directions, and use encoder parts of transformers to learn a representation for each token.

(41) In some embodiments, a pre-trained transformer **352** trained with large amounts of general-purpose text is then trained with custom enterprise corpus data (e.g., historical program design data) for accurate sentence generation. The transformer **352** solves sequence to sequence issues while handling long-range issues. Since the design changes in code in natural language are essentially a sequence of words in the body of text, and the output sentence is also a sequence of words, this can be modeled as a many-to-many sequence-to-sequence problem which the transformer **352** solves.

(42) A many-to-many sequence-to-sequence configuration has two core building blocks (encoder and decoder) and one supporting capability called an “attention mechanism.” The encoder-decoder architecture solves sequence-to-sequence problems like text generation or sentence generation tasks where input and output sequences are of different lengths. Considering an input textual message is similar to a time series model where the words come one after another in time and/or space, the transformer **352** comprises a sophisticated encoder-decoder with a multi-head attention mechanism.

(43) The architecture of a transformer **352** in an illustrative embodiment is shown in FIG. 3B. Referring to FIG. 3B, the encoder **370** is composed of a stack of a $N=6$ identical layers. Each layer has two sub-layers. The first sub-layer includes a multi-head self-attention mechanism **371**, and the second sub-layer includes a fully connected feed-forward network **372**. A residual connection is employed around each of the two sub-layers, followed by layer normalization **373-1**, **373-2**. The output of each encoder sub-layer is $\text{LayerNorm}(x + \text{Sublayer}(x))$, where $\text{Sublayer}(x)$ is the function implemented by the sub-layer. The decoder **380** is also composed of a stack of $N=6$ identical layers. Like each encoder layer, a layer of the decoder **380** includes two sub-layers including a multi-head self-attention mechanism **381**, and a fully connected feed-forward network **382**. Each layer of the decoder **380** further includes a third sub-layer comprising a masked multi-head self-attention mechanism **384**. The third sub-layer performs multi-head attention over the output of the encoder stack. Similar to the encoder, residual connections around each of the sub-layers are employed, followed by layer normalization **383-1**, **383-2** and **383-2**. The masked multi-head self-attention mechanism **384** prevents positions from attending to subsequent positions. This masking, combined with the fact that output embeddings are offset by one position, ensures that predictions for position i can depend only on known outputs at positions less than i . See Ashish Vaswani et al., *Attention Is All You Need*, 31.sup.st Conference on Neural Information Processing Systems (NIPS 2017) (ArXiv Paper No. 1706.03762), which is incorporated by reference herein.

(44) Illustrative embodiments utilize a Key2Text (K2T) or an OpenAI™ GPT2 transformer pre-trained with large amounts (e.g., millions of instances) of textual corpus data using, for example, PyTorch® and/or Tensorflow® software. The textual corpus data used for pre-training comprises, for example, community data from sources such as, but not necessarily limited to, Wikipedia®, news sources, social media (e.g., Twitter®) feeds, etc. Considering this data will involve a massive amount of enterprise specific design document data (including specific lingo like APEX, LIGHTNING, MAESTRO, etc.), the transformer models are customized and re-trained with domain-specific data.

(45) Illustrative embodiments utilize a Key2Text Python® package that leverages pre-trained K2T-base transformers to generate word combinations (e.g., sentences, phrases, etc.) from a set of input words. The package is built on top of a T5 transformer model and simplifies the APIs to use the model. FIG. 4 depicts example pseudocode **400** for leveraging Key2Text transformers to generate word combinations from a set of input words in an illustrative embodiment.

(46) FIG. 5 depicts example pseudocode **500** for passing words for product attributes as a list of text to a model for sentence generation. In illustrative embodiments, a model is created from a pipeline. For example, a K2T-base that is based on a T5-base transformer and pre-trained with general purpose language data is indicated. Hyperparameters like the number of beams (e.g., the number of steps for each search path or probable words/text) and the no repeat n-gram size (e.g., the size of an n-gram that cannot occur more than once) are specified. As shown in FIG. 5, words for product attributes are passed as a list of text to the model for sentence generation.

(47) Another approach in illustrative embodiments is to leverage an advanced OpenAI™ GPT2 transformer, which is trained using a massive amount of general-purpose text and capable of generating multiple word combinations from the same input words. A pre-trained GPT2 model is created from a transformer pipeline and the attribute values are passed in concatenated text to generate word combinations. FIG. 6 depicts example pseudocode **600** for generating a pre-trained GPT2 transformer model from a transformer pipeline and passing attribute values in concatenated text to generate word combinations.

(48) In illustrative embodiments, a pre-trained transformer is augmented with training data from corpus data that includes enterprise specific domain data (e.g., historical data from program design data corpus **154**). This can be achieved by loading and pre-processing (e.g., removing stop words, emojis, etc., perform stemming, lemmatization, etc.) custom training datasets to prepare for tokenization. Tokenizing converts words to numbers, which facilitates building of word vectors for NLP tasks. Tokenization can be done using a HuggingFace function “DistilBertTokenizerFast().” Once the model is augmented with a domain specific corpus, generated code change descriptions will be highly accurate and standardized. These generated code change descriptions can be included in design documents, thus enabling automated synchronization of code to design documents, thereby providing capabilities not offered by conventional approaches.

(49) In the routing and updating stage, output content (e.g., a generated code change description) from the description generation engine **150** is routed to a selected one of the document repositories **103** (e.g., Wiki, Jira, Confluence, etc.) via a corresponding repository interface **162** associated with the selected one of the document repositories **103**. The repository interfaces **162** are configured to construct URLs using metadata received from the data formatting engine **140**.

(50) As noted previously, the metadata comprises, for example, identifying information of an application for which the code changes have been made (e.g., application name or other identifier), identifying information of the document repository (e.g., URIs, URLs, macros, annotations, etc.) including the design documentation corresponding to the code changes, and/or identifying information of one or more documents in the document repository corresponding to the code changes. Based at least in part on the metadata, the document repository selection layer **161** of the routing engine **160** identifies to which one of the document repositories **103** the generated code change description should be sent, and determines a location of the identified document repository

103. The location identification layer **163** determines a location of any documents in the identified document repository **103** corresponding to the code changes, and a location within a given document where to add the generated description. In some embodiments, the location identification layer **163** identifies a location to update within a document based on macros and annotation. The location identification layer **163** constructs a URL to be used in connection with the transmission of the natural language description to the document repository, wherein the URL corresponds to one or more of the location of the document repository, the location of the one or more documents and the location within the one or more documents. In a non-limiting example, metadata from the data formatting engine **140** may include the following: Base URL:

<https://confluence.dell.com/display/EISB> APP Name: order-management

(51) Based on this metadata, the location identification layer **163** may construct the following URL to be used in connection with the transmission of the natural language description to the Confluence document repository: <https://confluence.dell.com/display/EISB/order-management>.

(52) Referring to block **170** of FIG. 2, (create/update document **170**), the code change description will be added to the Confluence document repository in an existing document or a new document can be created therein to add the update in accordance with the constructed URL. The location identification layer **163** is further configured to scan pages of a document repository **103** for updating. For example, referring back to the operational example of creating a rest service to provide order details for a given order number, the location identification layer **163** may scan a Confluence page to update a “/getOrders” API endpoint section based on the following annotation that may be present in code changes:

(53)
`@RequestMapping(value = “ / order / {id} / {orderType} / {region}”, method = RequestMethod . GET).`

(54) The new functionality will be reflected in the appropriate technical document in a given repository by including the generated natural language description of the one or more code changes. For example, FIG. 9 depicts design documentation **900** updated with a generated description of code changes that states “This rest endpoint fetches all the order details based on order ID for a specific order type for the specified region.”

(55) In an operational example, code changes may relate to software used in connection with requests for proposals and negotiation of costs for externally procured direct material components and sub-assembly parts from a first application into a second application. In connection with this operational example, FIGS. **10A** and **10B** depict collected data **1001** and **1002** corresponding to first code changes with highlighted key words, and FIG. **11** depicts collected data **1100** corresponding to second code changes with highlighted key words. In connection with FIGS. **10A** and **10B**, based at least in part on the highlighted key words, the natural language description of the functionality associated with the code change generated by the description generation engine **150** may state: “Finding the currency index for a given request using binary search techniques.” In connection with FIG. **11**, based at least in part on the highlighted key words, the natural language description of the functionality associated with the code change generated by the description generation engine **150** may state: “Extracting the requested unit ID and unit code details from the units list for all the parts requested.”

(56) For additional code changes (not shown), the natural language description of the functionality associated with the code changes generated by the description generation engine **150** may state: “Designwin sends negotiated costs for externally procured direct material components and sub-assembly parts. Extracts the requested unit ID and unit code details from the units list for all the parts requested. Then, extract the requested award price details from the award price list of polydyne for all the parts requested. Similarly extract manufacturers and suppliers list for the given request from polydyne. Then, consolidate and prepare XML payload and send to E2OPEN.”

(57) According to one or more embodiments, the document repositories **103**, code repository **105**, program design data corpus **154** and other data corpuses, repositories or databases referred to

herein can be configured according to a relational database management system (RDBMS) (e.g., PostgreSQL). In some embodiments, the document repositories **103**, code repository **105**, program design data corpus **154** and other data corpuses, repositories or databases referred to herein are implemented using one or more storage systems or devices associated with the design documentation management platform **110**. In some embodiments, one or more of the storage systems utilized to implement the document repositories **103**, code repository **105**, program design data corpus **154** and other data corpuses, repositories or databases referred to herein comprise a scale-out all-flash content addressable storage array or other type of storage array.

(58) The term “storage system” as used herein is therefore intended to be broadly construed, and should not be viewed as being limited to content addressable storage systems or flash-based storage systems. A given storage system as the term is broadly used herein can comprise, for example, network-attached storage (NAS), storage area networks (SANs), direct-attached storage (DAS) and distributed DAS, as well as combinations of these and other storage types, including software-defined storage.

(59) Other particular types of storage products that can be used in implementing storage systems in illustrative embodiments include all-flash and hybrid flash storage arrays, software-defined storage products, cloud storage products, object-based storage products, and scale-out NAS clusters. Combinations of multiple ones of these and other storage products can also be used in implementing a given storage system in an illustrative embodiment.

(60) Although shown as elements of the design documentation management platform **110**, the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150** and/or routing engine **160** in other embodiments can be implemented at least in part externally to the design documentation management platform **110**, for example, as stand-alone servers, sets of servers or other types of systems coupled to the network **104**. For example, the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150** and/or routing engine **160** may be provided as cloud services accessible by the design documentation management platform **110**.

(61) The code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150** and/or routing engine **160** in the FIG. 1 embodiment are each assumed to be implemented using at least one processing device. Each such processing device generally comprises at least one processor and an associated memory, and implements one or more functional modules for controlling certain features of the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150** and/or routing engine **160**.

(62) At least portions of the design documentation management platform **110** and the elements thereof may be implemented at least in part in the form of software that is stored in memory and executed by a processor. The design documentation management platform **110** and the elements thereof comprise further hardware and software required for running the design documentation management platform **110**, including, but not necessarily limited to, on-premises or cloud-based centralized hardware, graphics processing unit (GPU) hardware, virtualization infrastructure software and hardware, Docker containers, networking software and hardware, and cloud infrastructure software and hardware.

(63) Although the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150**, routing engine **160** and other elements of the design documentation management platform **110** in the present embodiment are shown as part of the design documentation management platform **110**, at least a portion of the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150**, routing engine **160** and other elements of the design documentation management platform **110** in other embodiments may be implemented on one or more other processing platforms that are accessible to the design documentation management platform **110** over one or more networks. Such

elements can each be implemented at least in part within another system element or at least in part utilizing one or more stand-alone elements coupled to the network **104**.

(64) It is assumed that the design documentation management platform **110** in the FIG. **1** embodiment and other processing platforms referred to herein are each implemented using a plurality of processing devices each having a processor coupled to a memory. Such processing devices can illustratively include particular arrangements of compute, storage and network resources. For example, processing devices in some embodiments are implemented at least in part utilizing virtual resources such as virtual machines (VMs) or LXC's, or combinations of both as in an arrangement in which Docker containers or other types of LXC's are configured to run on VMs.

(65) The term "processing platform" as used herein is intended to be broadly construed so as to encompass, by way of illustration and without limitation, multiple sets of processing devices and one or more associated storage systems that are configured to communicate over one or more networks.

(66) As a more particular example, the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150**, routing engine **160** and other elements of the design documentation management platform **110**, and the elements thereof can each be implemented in the form of one or more LXC's running on one or more VMs. Other arrangements of one or more processing devices of a processing platform can be used to implement the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150**, routing engine **160**, as well as other elements of the design documentation management platform **110**. Other portions of the system **100** can similarly be implemented using one or more processing devices of at least one processing platform.

(67) Distributed implementations of the system **100** are possible, in which certain elements of the system reside in one data center in a first geographic location while other elements of the system reside in one or more other data centers in one or more other geographic locations that are potentially remote from the first geographic location. Thus, it is possible in some implementations of the system **100** for different portions of the design documentation management platform **110** to reside in different data centers. Numerous other distributed implementations of the design documentation management platform **110** are possible.

(68) Accordingly, one or each of the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150**, routing engine **160** and other elements of the design documentation management platform **110** can each be implemented in a distributed manner so as to comprise a plurality of distributed elements implemented on respective ones of a plurality of compute nodes of the design documentation management platform **110**.

(69) It is to be appreciated that these and other features of illustrative embodiments are presented by way of example only, and should not be construed as limiting in any way. Accordingly, different numbers, types and arrangements of system elements such as the code development engine **120**, content collection engine **130**, data formatting engine **140**, description generation engine **150**, routing engine **160** and other elements of the design documentation management platform **110**, and the portions thereof can be used in other embodiments.

(70) It should be understood that the particular sets of modules and other elements implemented in the system **100** as illustrated in FIG. **1** are presented by way of example only. In other embodiments, only subsets of these elements, or additional or alternative sets of elements, may be used, and such elements may exhibit alternative functionality and configurations.

(71) For example, as indicated previously, in some illustrative embodiments, functionality for the design documentation management platform can be offered to cloud infrastructure customers or other users as part of FaaS, CaaS and/or PaaS offerings.

(72) The operation of the information processing system **100** will now be described in further detail with reference to the flow diagram of FIG. **12**. With reference to FIG. **12**, a process **1200** for design documentation management as shown includes steps **1202** through **1210**, and is suitable for use in

the system **100** but is more generally applicable to other types of information processing systems comprising a design documentation management platform configured for updating design documentation in response to committed code changes.

(73) In step **1202**, data corresponding to one or more code changes is collected in response to committing of the one or more code changes to a code repository. Collecting of the data corresponding to the one or more code changes may be performed through an API of a software development platform (e.g., Gitlab). In step **1204**, the data is formatted into at least one data string. The formatting comprises removing redundancies from the data and determining and maintaining portions of the data specifying the one or more code changes.

(74) In step **1206**, the at least one data string is inputted to one or machine learning models. In step **1208**, using the one or machine learning models, a natural language description of the one or more code changes is generated based at least in part on the at least one data string. The generating comprises using at least one natural language generation algorithm which utilizes one or more transformers to generate one or more word combinations in the natural language description. The at least one natural language generation algorithm utilizes one or more neural networks in combination with the one or more transformers to generate the one or more word combinations. The at least one natural language generation algorithm is trained with historical program design data. Step **1210** includes causing transmission of the natural language description of the one or more code changes to a document repository.

(75) In illustrative embodiments, the data comprises the one or more code changes and metadata associated with the one or more code changes. The metadata comprises at least one of identifying information of an application for which the one or code changes have been made, identifying information of the document repository and identifying information of one or more documents in the document repository corresponding to the one or more code changes. Based at least in part on the metadata, at least one of the following is determined: (i) a location of the document repository, (ii) a location of the one or more documents in the document repository corresponding to the one or more code changes, and (iii) a location within the one or more documents where to include the natural language description of the one or more code changes.

(76) A URL to be used in connection with the transmission of the natural language description to the document repository is constructed, wherein the URL corresponds to one or more of the location of the document repository, the location of the one or more documents and the location within the one or more documents. The process may further include causing the one or more documents in the document repository to be updated to include the natural language description of the one or more code changes.

(77) It is to be appreciated that the FIG. **12** process and other features and functionality described above can be adapted for use with other types of information systems configured to execute design documentation management services in a design documentation management platform or other type of platform.

(78) The particular processing operations and other system functionality described in conjunction with the flow diagram of FIG. **12** are therefore presented by way of illustrative example only, and should not be construed as limiting the scope of the disclosure in any way. Alternative embodiments can use other types of processing operations. For example, the ordering of the process steps may be varied in other embodiments, or certain steps may be performed at least in part concurrently with one another rather than serially. Also, one or more of the process steps may be repeated periodically, or multiple instances of the process can be performed in parallel with one another.

(79) Functionality such as that described in conjunction with the flow diagram of FIG. **12** can be implemented at least in part in the form of one or more software programs stored in memory and executed by a processor of a processing device such as a computer or server. As will be described below, a memory or other storage device having executable program code of one or more software

programs embodied therein is an example of what is more generally referred to herein as a “processor-readable storage medium.”

(80) Illustrative embodiments of systems with a design documentation management platform as disclosed herein can provide a number of significant advantages relative to conventional arrangements. For example, the design documentation management platform advantageously updates design documents in response to new changes or enhancements. In more detail, a framework retrieves the latest commit details in real time along with corresponding metadata, and a machine learning model generates a description of the code changes in the commit details. As an additional advantage, the framework updates the correct document in the right location as a real time response to committing the code change. The location where the document is updated is added as part of metadata in the codebase.

(81) The embodiments provide a technical solution that automatically transforms code changes in a repository to descriptive text in the design document. The code changes are received through APIs and formatted into data strings that can be input to a machine learning model for generation of descriptions of the functionality of the code changes. The machine learning model leverages advanced NLP, NLU, NLG and neural network techniques and trains a transformer using a domain specific design document corpus to generate natural language descriptions of code changes. Using macros and annotations for automatic updates to the documents, the framework intelligently identifies locations in the design documents where to incorporate the updates.

(82) It is to be appreciated that the particular advantages described above and elsewhere herein are associated with particular illustrative embodiments and need not be present in other embodiments. Also, the particular types of information processing system features and functionality as illustrated in the drawings and described above are exemplary only, and numerous other arrangements may be used in other embodiments.

(83) As noted above, at least portions of the information processing system **100** may be implemented using one or more processing platforms. A given such processing platform comprises at least one processing device comprising a processor coupled to a memory. The processor and memory in some embodiments comprise respective processor and memory elements of a virtual machine or container provided using one or more underlying physical machines. The term “processing device” as used herein is intended to be broadly construed so as to encompass a wide variety of different arrangements of physical processors, memories and other device components as well as virtual instances of such components. For example, a “processing device” in some embodiments can comprise or be executed across one or more virtual processors. Processing devices can therefore be physical or virtual and can be executed across one or more physical or virtual processors. It should also be noted that a given virtual device can be mapped to a portion of a physical one.

(84) Some illustrative embodiments of a processing platform that may be used to implement at least a portion of an information processing system comprise cloud infrastructure including virtual machines and/or container sets implemented using a virtualization infrastructure that runs on a physical infrastructure. The cloud infrastructure further comprises sets of applications running on respective ones of the virtual machines and/or container sets.

(85) These and other types of cloud infrastructure can be used to provide what is also referred to herein as a multi-tenant environment. One or more system elements such as the design documentation management platform **110** or portions thereof are illustratively implemented for use by tenants of such a multi-tenant environment.

(86) As mentioned previously, cloud infrastructure as disclosed herein can include cloud-based systems. Virtual machines provided in such systems can be used to implement at least portions of one or more of a computer system and a design documentation management platform in illustrative embodiments. These and other cloud-based systems in illustrative embodiments can include object stores.

(87) Illustrative embodiments of processing platforms will now be described in greater detail with reference to FIGS. **13** and **14**. Although described in the context of system **100**, these platforms may also be used to implement at least portions of other information processing systems in other embodiments.

(88) FIG. **13** shows an example processing platform comprising cloud infrastructure **1300**. The cloud infrastructure **1300** comprises a combination of physical and virtual processing resources that may be utilized to implement at least a portion of the information processing system **100**. The cloud infrastructure **1300** comprises multiple virtual machines (VMs) and/or container sets **1302-1**, **1302-2**, . . . **1302-L** implemented using virtualization infrastructure **1304**. The virtualization infrastructure **1304** runs on physical infrastructure **1305**, and illustratively comprises one or more hypervisors and/or operating system level virtualization infrastructure. The operating system level virtualization infrastructure illustratively comprises kernel control groups of a Linux operating system or other type of operating system.

(89) The cloud infrastructure **1300** further comprises sets of applications **1310-1**, **1310-2**, **1310-L** running on respective ones of the VMs/container sets **1302-1**, **1302-2**, . . . **1302-L** under the control of the virtualization infrastructure **1304**. The VMs/container sets **1302** may comprise respective VMs, respective sets of one or more containers, or respective sets of one or more containers running in VMs.

(90) In some implementations of the FIG. **13** embodiment, the VMs/container sets **1302** comprise respective VMs implemented using virtualization infrastructure **1304** that comprises at least one hypervisor. A hypervisor platform may be used to implement a hypervisor within the virtualization infrastructure **1304**, where the hypervisor platform has an associated virtual infrastructure management system. The underlying physical machines may comprise one or more distributed processing platforms that include one or more storage systems.

(91) In other implementations of the FIG. **13** embodiment, the VMs/container sets **1302** comprise respective containers implemented using virtualization infrastructure **1304** that provides operating system level virtualization functionality, such as support for Docker containers running on bare metal hosts, or Docker containers running on VMs. The containers are illustratively implemented using respective kernel control groups of the operating system.

(92) As is apparent from the above, one or more of the processing modules or other components of system **100** may each run on a computer, server, storage device or other processing platform element. A given such element may be viewed as an example of what is more generally referred to herein as a “processing device.” The cloud infrastructure **1300** shown in FIG. **13** may represent at least a portion of one processing platform. Another example of such a processing platform is processing platform **1400** shown in FIG. **14**.

(93) The processing platform **1400** in this embodiment comprises a portion of system **100** and includes a plurality of processing devices, denoted **1402-1**, **1402-2**, **1402-3**, . . . **1402-K**, which communicate with one another over a network **1404**.

(94) The network **1404** may comprise any type of network, including by way of example a global computer network such as the Internet, a WAN, a LAN, a satellite network, a telephone or cable network, a cellular network, a wireless network such as a WiFi or WiMAX network, or various portions or combinations of these and other types of networks.

(95) The processing device **1402-1** in the processing platform **1400** comprises a processor **1410** coupled to a memory **1412**. The processor **1410** may comprise a microprocessor, a microcontroller, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a central processing unit (CPU), a graphical processing unit (GPU), a tensor processing unit (TPU), a video processing unit (VPU) or other type of processing circuitry, as well as portions or combinations of such circuitry elements.

(96) The memory **1412** may comprise random access memory (RAM), read-only memory (ROM), flash memory or other types of memory, in any combination. The memory **1412** and other

memories disclosed herein should be viewed as illustrative examples of what are more generally referred to as “processor-readable storage media” storing executable program code of one or more software programs.

(97) Articles of manufacture comprising such processor-readable storage media are considered illustrative embodiments. A given such article of manufacture may comprise, for example, a storage array, a storage disk or an integrated circuit containing RAM, ROM, flash memory or other electronic memory, or any of a wide variety of other types of computer program products. The term “article of manufacture” as used herein should be understood to exclude transitory, propagating signals. Numerous other types of computer program products comprising processor-readable storage media can be used.

(98) Also included in the processing device **1402-1** is network interface circuitry **1414**, which is used to interface the processing device with the network **1404** and other system components, and may comprise conventional transceivers.

(99) The other processing devices **1402** of the processing platform **1400** are assumed to be configured in a manner similar to that shown for processing device **1402-1** in the figure.

(100) Again, the particular processing platform **1400** shown in the figure is presented by way of example only, and system **100** may include additional or alternative processing platforms, as well as numerous distinct processing platforms in any combination, with each such platform comprising one or more computers, servers, storage devices or other processing devices.

(101) For example, other processing platforms used to implement illustrative embodiments can comprise converged infrastructure.

(102) It should therefore be understood that in other embodiments different arrangements of additional or alternative elements may be used. At least a subset of these elements may be collectively implemented on a common processing platform, or each such element may be implemented on a separate processing platform.

(103) As indicated previously, components of an information processing system as disclosed herein can be implemented at least in part in the form of one or more software programs stored in memory and executed by a processor of a processing device. For example, at least portions of the functionality of one or more elements of the design documentation management platform **110** as disclosed herein are illustratively implemented in the form of software running on one or more processing devices.

(104) It should again be emphasized that the above-described embodiments are presented for purposes of illustration only. Many variations and other alternative embodiments may be used. For example, the disclosed techniques are applicable to a wide variety of other types of information processing systems and design documentation management platforms. Also, the particular configurations of system and device elements and associated processing operations illustratively shown in the drawings can be varied in other embodiments. Moreover, the various assumptions made above in the course of describing the illustrative embodiments should also be viewed as exemplary rather than as requirements or limitations of the disclosure. Numerous other alternative embodiments within the scope of the appended claims will be readily apparent to those skilled in the art.

Claims

1. A method comprising: re-training one or more pre-trained machine learning models with enterprise-specific historical program design data to generate one or more augmented machine learning models; collecting data corresponding to one or more code changes in response to committing of the one or more code changes to a code repository, wherein the data comprises the one or more code changes and metadata associated with the one or more code changes; formatting the data into at least one data string; inputting the at least one data string to the one or more

augmented machine learning models; generating, using the one or more augmented machine learning models, a natural language description of the one or more code changes based at least in part on the at least one data string; determining, based on the metadata, a location of a document repository, a location of one or more documents in the document repository corresponding to the one or more code changes, and a location within the one or more documents where to include the natural language description of the one or more code changes; and automatically causing transmission of the natural language description of the one or more code changes to the location within the one or more documents of the document repository; wherein the steps of the method are executed by a processing device operatively coupled to a memory.

2. The method of claim 1 wherein the metadata comprises at least one of identifying information of an application for which the one or code changes have been made, identifying information of the document repository and identifying information of one or more documents in the document repository corresponding to the one or more code changes.

3. The method of claim 1 further comprising constructing a uniform resource locator to be used in connection with the transmission of the natural language description to the document repository, wherein the uniform resource locator corresponds to one or more of the location of the document repository, the location of the one or more documents and the location within the one or more documents.

4. The method of claim 1 further comprising causing the one or more documents in the document repository to be updated to include the natural language description of the one or more code changes.

5. The method of claim 1 wherein the generating comprises using at least one natural language generation algorithm which utilizes one or more transformers to generate one or more word combinations in the natural language description.

6. The method of claim 5 wherein the at least one natural language generation algorithm utilizes one or more neural networks in combination with the one or more transformers to generate the one or more word combinations.

7. The method of claim 1 wherein the collecting of the data corresponding to the one or more code changes is performed through an application programming interface of a software development platform.

8. The method of claim 1 wherein the formatting comprises removing redundancies from the data and determining and maintaining portions of the data specifying the one or more code changes.

9. An apparatus comprising at least one processing platform, the processing platform comprising at least one processor coupled to at least one memory, the at least one processing platform, when executing program code, is configured: to re-train one or more pre-trained machine learning models with enterprise-specific historical program design data to generate one or more augmented machine learning models; to collect data corresponding to one or more code changes in response to committing of the one or more code changes to a code repository, wherein the data comprises the one or more code changes and metadata associated with the one or more code changes; to format the data into at least one data string; to input the at least one data string to the one or more augmented machine learning models; to generate, using the one or more augmented machine learning models, a natural language description of the one or more code changes based at least in part on the at least one data string; to determine, based on the metadata, a location of a document repository, a location of one or more documents in the document repository corresponding to the one or more code changes, and a location within the one or more documents where to include the natural language description of the one or more code changes; and to automatically cause transmission of the natural language description of the one or more code changes to the location within the one or more documents of the document repository.

10. The apparatus of claim 9 wherein the metadata comprises at least one of identifying information of an application for which the one or code changes have been made, identifying

information of the document repository and identifying information of one or more documents in the document repository corresponding to the one or more code changes.

11. The apparatus of claim 9 wherein the at least one processing platform, when executing program code, is further configured to construct a uniform resource locator to be used in connection with the transmission of the natural language description to the document repository, wherein the uniform resource locator corresponds to one or more of the location of the document repository, the location of the one or more documents and the location within the one or more documents.

12. The apparatus of claim 9, wherein the at least one processing platform, when executing program code, is further configured to cause the one or more documents in the document repository to be updated to include the natural language description of the one or more code changes.

13. The apparatus of claim 9, wherein the generating comprises using at least one natural language generation algorithm which utilizes one or more transformers to generate one or more word combinations in the natural language description.

14. The apparatus of claim 13, wherein the at least one natural language generation algorithm utilizes one or more neural networks in combination with the one or more transformers to generate the one or more word combinations.

15. An article of manufacture comprising a non-transitory processor-readable storage medium having stored therein program code of one or more software programs, wherein the program code when executed by at least one processing device causes the at least one processing device to perform the steps of: re-training one or more pre-trained machine learning models with enterprise-specific historical program design data to generate one or more augmented machine learning models; collecting data corresponding to one or more code changes in response to committing of the one or more code changes to a code repository, wherein the data comprises the one or more code changes and metadata associated with the one or more code changes; formatting the data into at least one data string; inputting the at least one data string to the one or more augmented machine learning models; generating, using the one or more augmented machine learning models, a natural language description of the one or more code changes based at least in part on the at least one data string; determining, based on the metadata, a location of a document repository, a location of one or more documents in the document repository corresponding to the one or more code changes, and a location within the one or more documents where to include the natural language description of the one or more code changes; and automatically causing transmission of the natural language description of the one or more code changes to the location within the one or more documents of the document repository.

16. The article of manufacture of claim 15 wherein the metadata comprises at least one of identifying information of an application for which the one or code changes have been made, identifying information of the document repository and identifying information of one or more documents in the document repository corresponding to the one or more code changes.

17. The article of manufacture of claim 15, wherein the program code when executed by at least one processing device further causes the at least one processing device to cause the one or more documents in the document repository to be updated to include the natural language description of the one or more code changes.

18. The article of manufacture of claim 15, wherein the generating comprises using at least one natural language generation algorithm which utilizes one or more transformers to generate one or more word combinations in the natural language description.

19. The article of manufacture of claim 18, wherein the at least one natural language generation algorithm utilizes one or more neural networks in combination with the one or more transformers to generate the one or more word combinations.

20. The article of manufacture of claim 15, wherein the collecting of the data corresponding to the one or more code changes is performed through an application programming interface of a software development platform.

