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(54) **ACCELERATING DATA-DRIVEN SCIENTIFIC DISCOVERY**

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(51) **Int. Cl.**

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G06Q 10/00	(2012.01)
G06T 11/20	(2006.01)
G06Q 10/06	(2012.01)
G06Q 20/38	(2012.01)

(52) **U.S. Cl.**

CPC ***G06T 11/206*** (2013.01); ***G06Q 10/0639*** (2013.01); ***G06Q 20/38*** (2013.01)

(58) **Field of Classification Search**

CPC G06F 11/206
USPC 345/440
See application file for complete search history.

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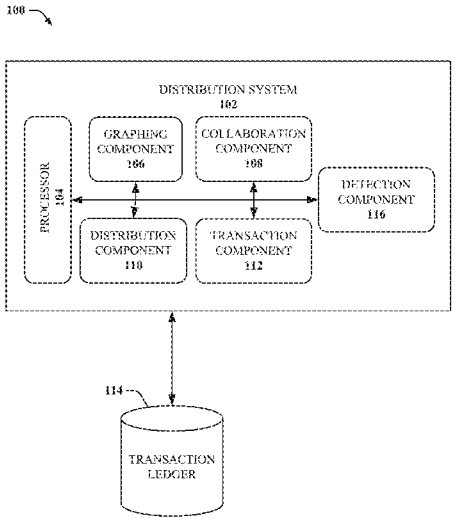
(57) **ABSTRACT**

Techniques facilitating using a distribution system for incentivizing and accelerating data driven scientific research are described herein. The distribution system can track the input of various parties involved in scientific research, and when a reward, monetary or otherwise, is realized for one or more outcomes of the scientific research, the distribution system can distribute the reward among the parties that provided the input. The relative levels and contributions of the parties can be tracked to ensure that an equitable portioning of the reward is realized. A directed graph can be formed based on the transactions, wherein the nodes correspond to entities, researchers, publications, and the edges correspond to relationships between the entities. The directed graph can be analyzed to determine the relative or absolute levels of contributions from each of the entities, and the rewards can be distributed based on the contribution levels.

18 Claims, 10 Drawing Sheets



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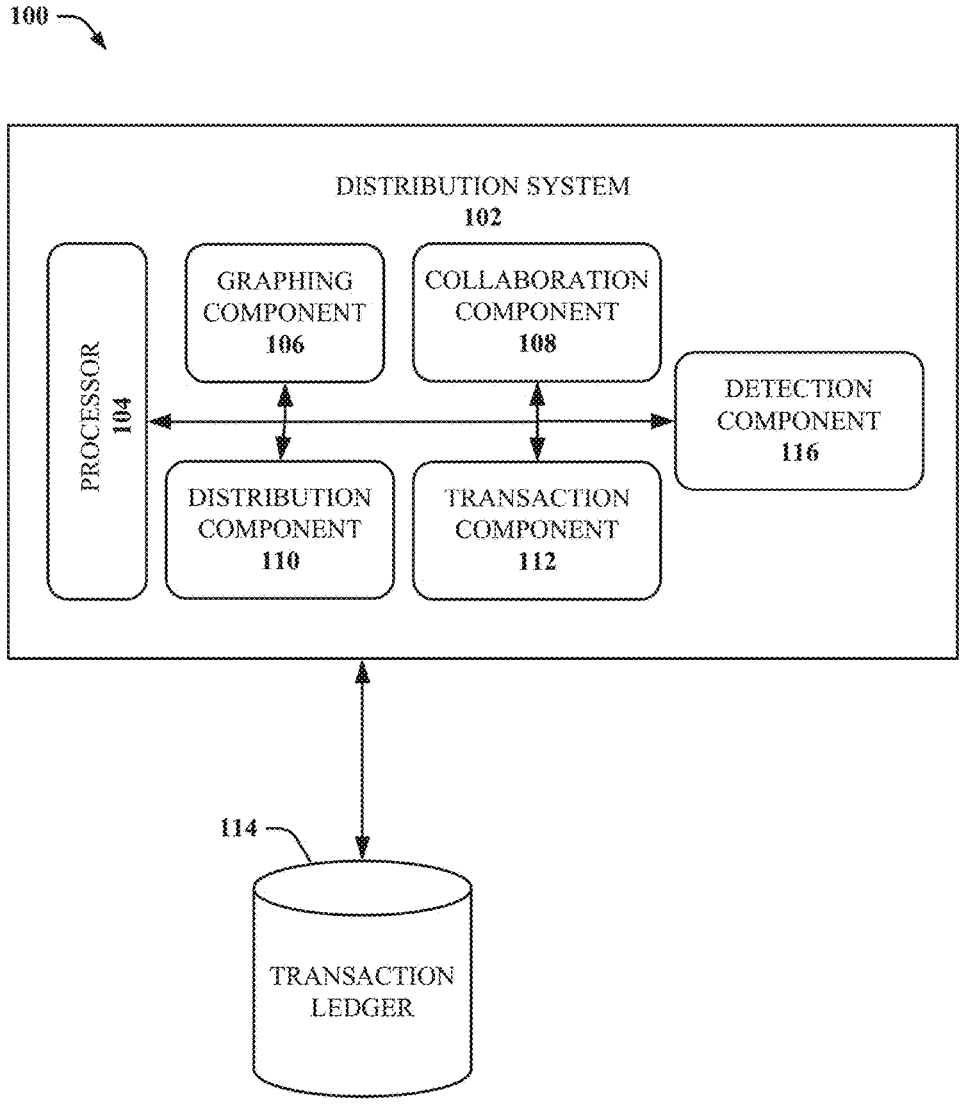
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DISTRIBUTION SYSTEM
102
PROCESSOR
104
GRAPHING
COMPONENT
106
COLLABORATION
COMPONENT
108
DETECTION
COMPONENT
116
DISTRIBUTION
COMPONENT
110
TRANSACTION
COMPONENT
112
114
TRANSACTION
LEDGER

FIG. 1

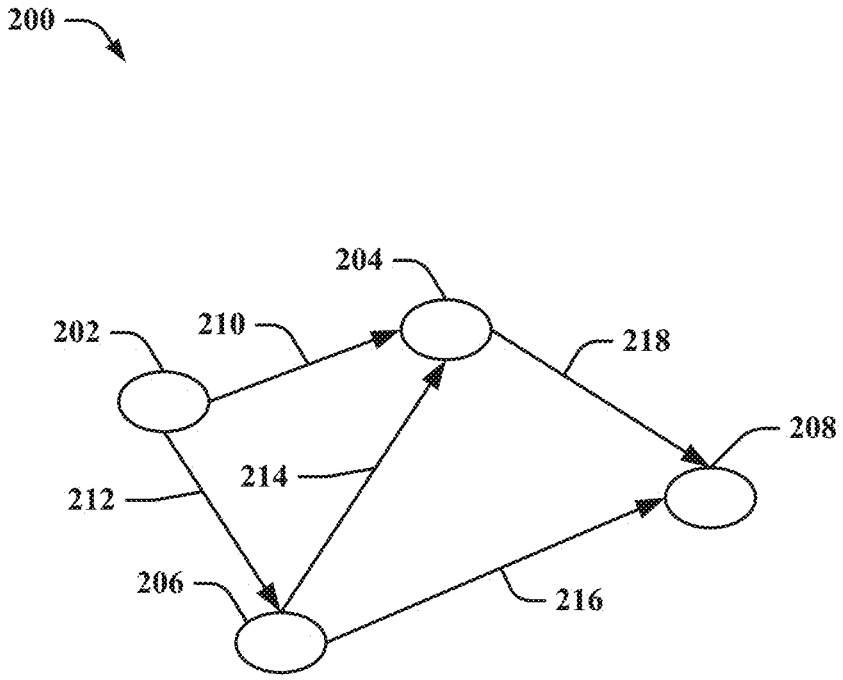


FIG. 2

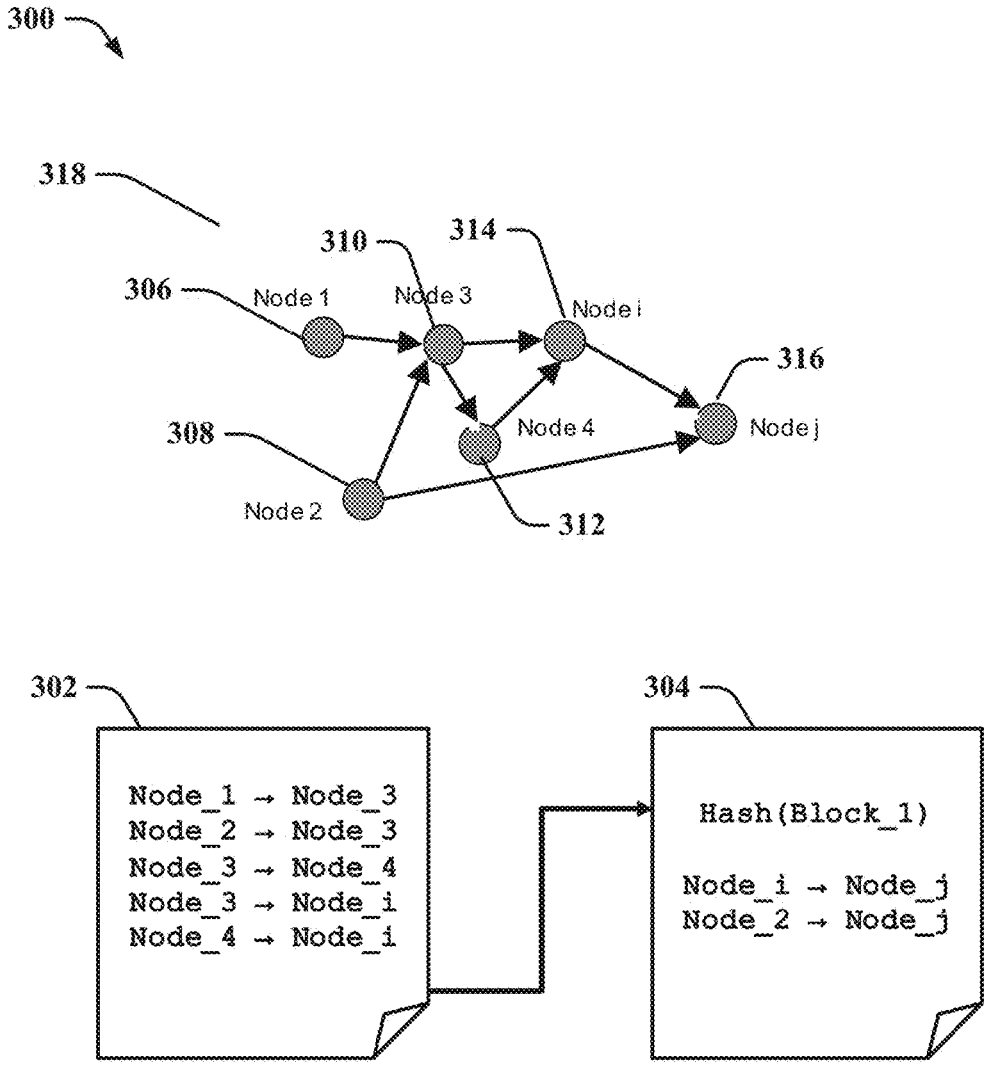

300
318
310
314
306
Node 1
Node 3
Node i
316
308
Node 4
Node j
Node 2
312
302
304
Node_1 → Node_3
Node_2 → Node_3
Node_3 → Node_4
Node_3 → Node_i
Node_4 → Node_i
Hash(Block_1)
Node_i → Node_j
Node_2 → Node_j

FIG. 3

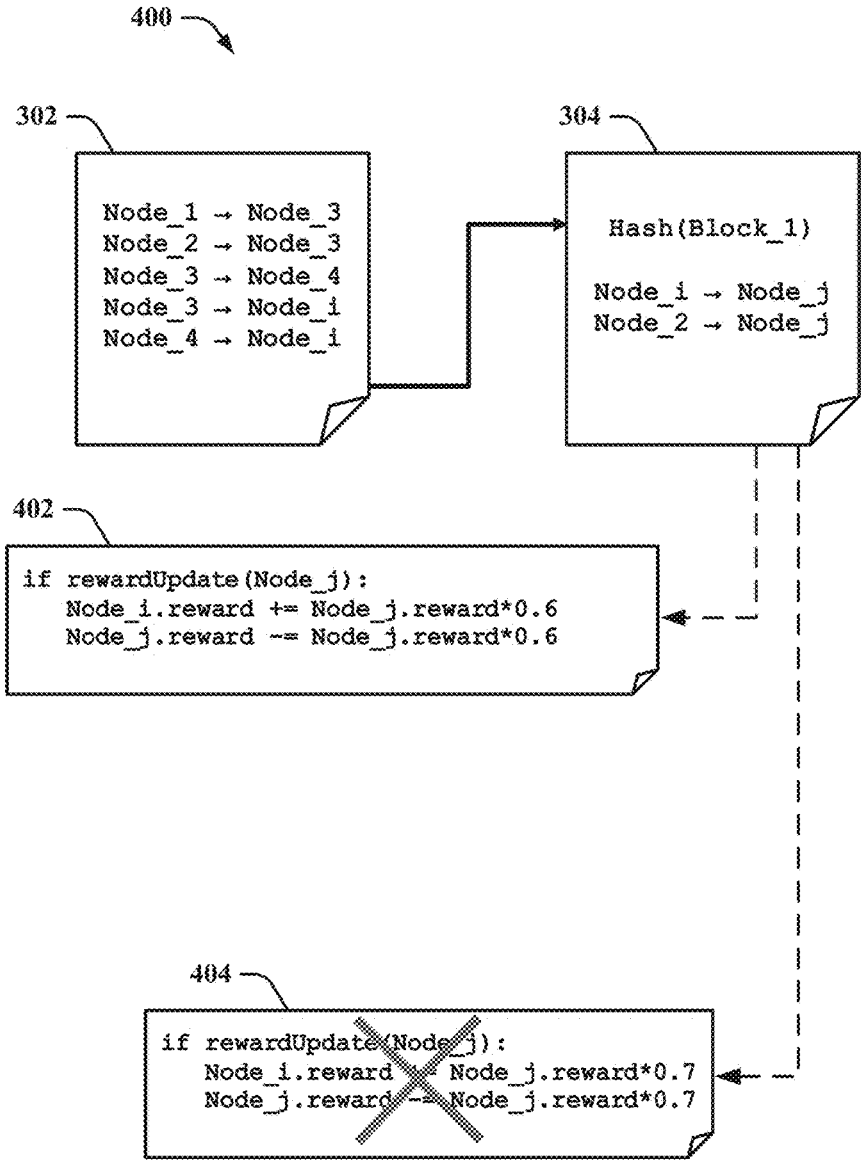
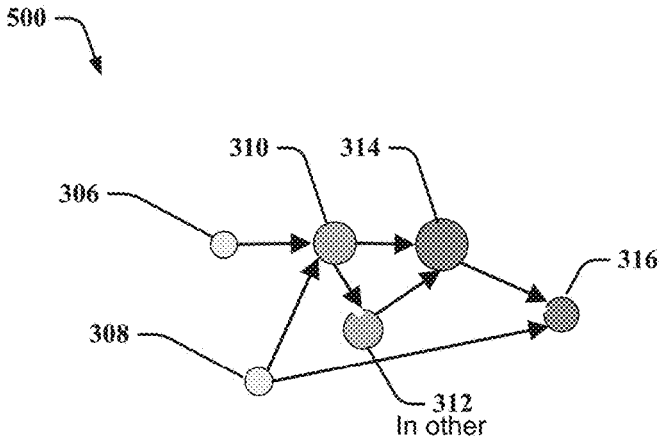

400
302
Node_1 → Node_3
Node_2 → Node_3
Node_3 → Node_4
Node_3 → Node_i
Node_4 → Node_i
304
Hash(Block_1)
Node_i → Node_j
Node_2 → Node_j
402
if rewardUpdate(Node_j):
Node_i.reward += Node_j.reward*0.6
Node_j.reward -= Node_j.reward*0.6
404
if rewardUpdate(Node_j):
Node_i.reward += Node_j.reward*0.7
Node_j.reward -= Node_j.reward*0.7

FIG. 4


500
310
314
306
316
308
312
In other

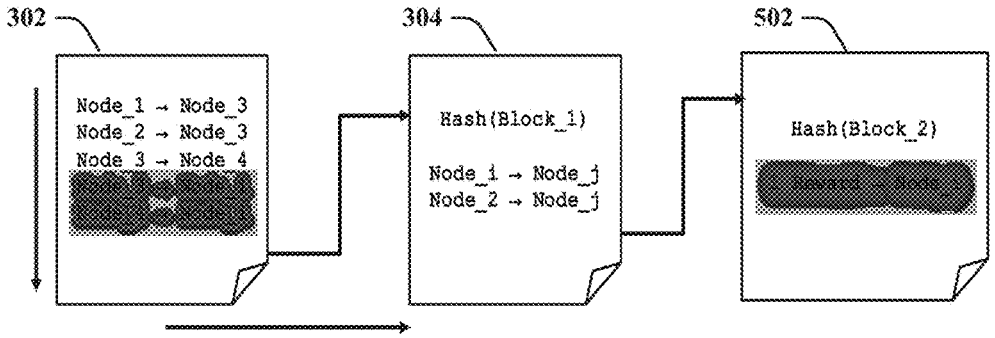

302
304
502
Node_1 → Node_3
Node_2 → Node_3
Node_3 → Node_4
Hash(Block_1)
Node_1 → Node_j
Node_2 → Node_j
Hash(Block_2)

FIG. 5

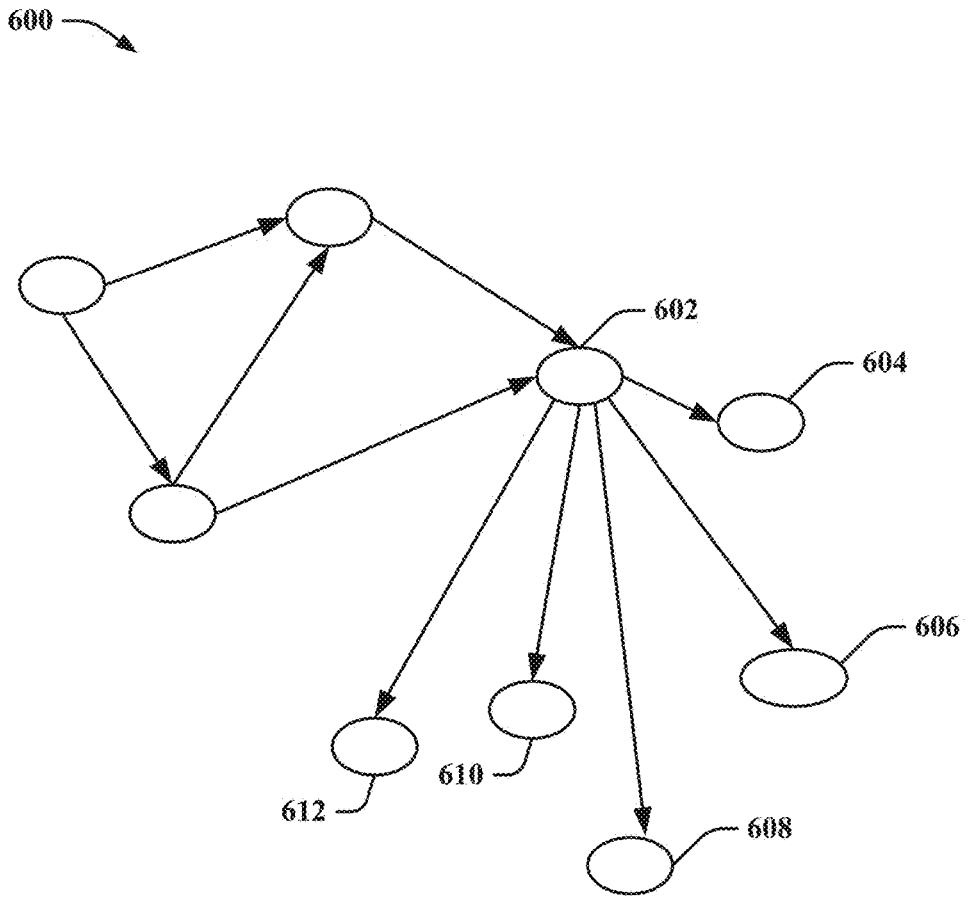


FIG. 6

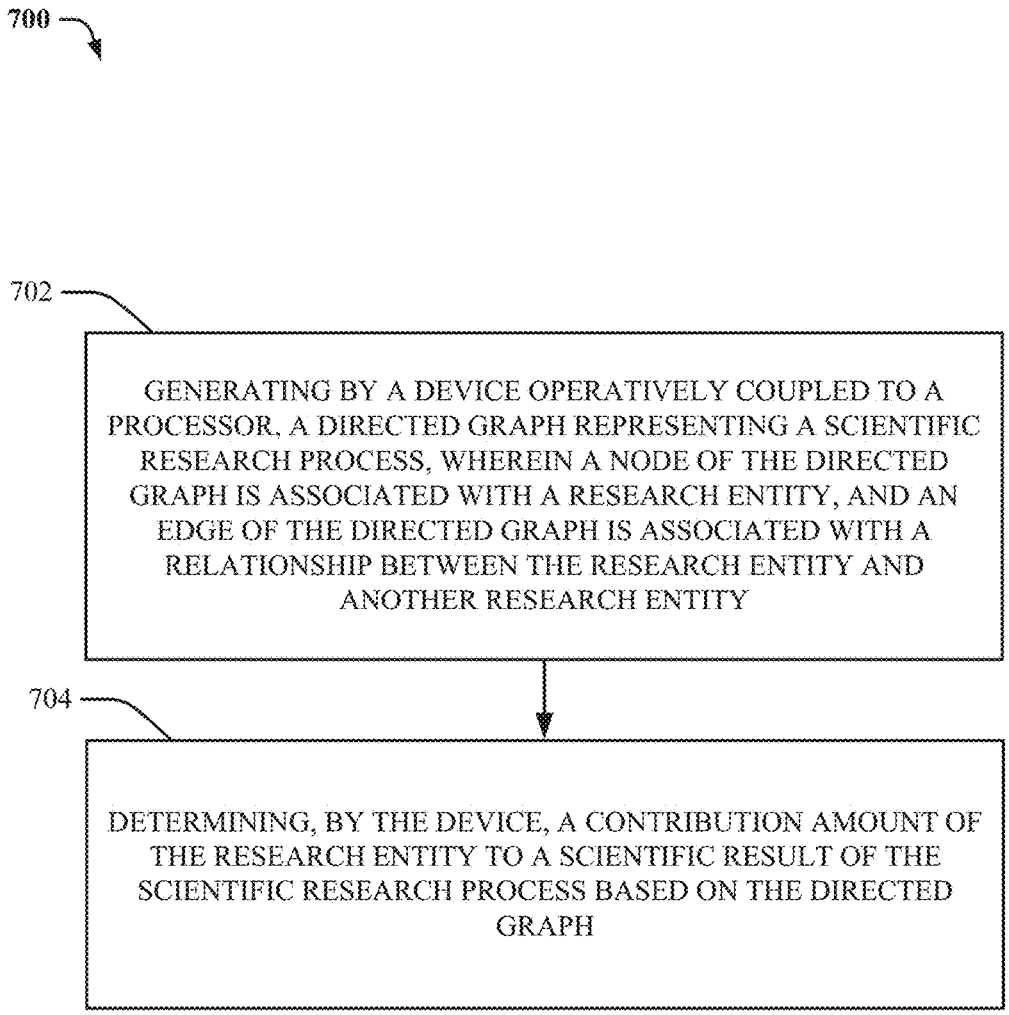

700
702
GENERATING BY A DEVICE OPERATIVELY COUPLED TO A PROCESSOR, A DIRECTED GRAPH REPRESENTING A SCIENTIFIC RESEARCH PROCESS, WHEREIN A NODE OF THE DIRECTED GRAPH IS ASSOCIATED WITH A RESEARCH ENTITY, AND AN EDGE OF THE DIRECTED GRAPH IS ASSOCIATED WITH A RELATIONSHIP BETWEEN THE RESEARCH ENTITY AND ANOTHER RESEARCH ENTITY
704
DETERMINING, BY THE DEVICE, A CONTRIBUTION AMOUNT OF THE RESEARCH ENTITY TO A SCIENTIFIC RESULT OF THE SCIENTIFIC RESEARCH PROCESS BASED ON THE DIRECTED GRAPH

FIG. 7

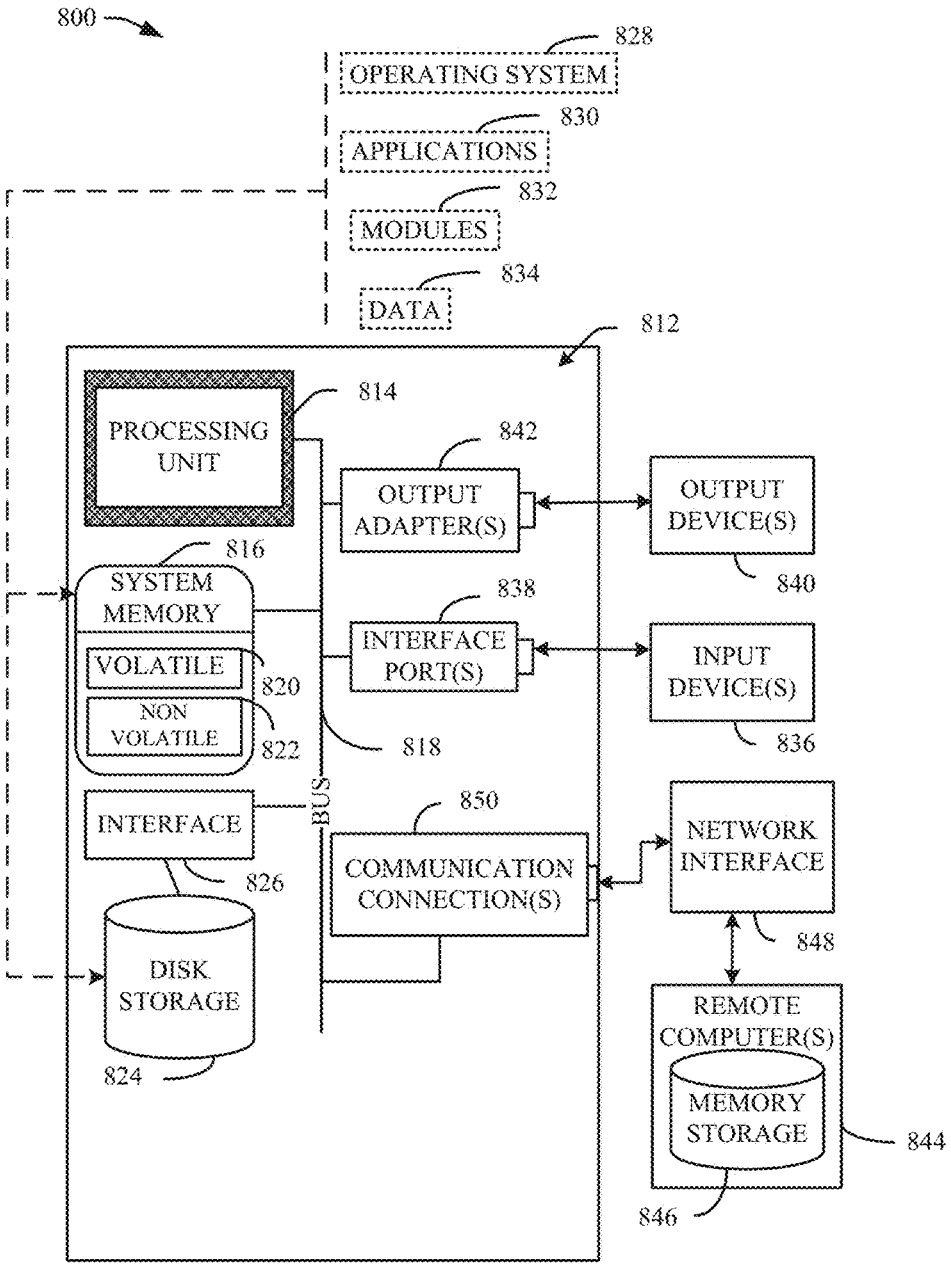

800
828
OPERATING SYSTEM
830
APPLICATIONS
832
MODULES
834
DATA
812
814
PROCESSING UNIT
842
OUTPUT ADAPTER(S)
OUTPUT DEVICE(S)
840
816
SYSTEM MEMORY
838
INTERFACE PORT(S)
INPUT DEVICE(S)
836
VOLATILE
820
NON VOLATILE
822
818
BUS
INTERFACE
826
850
COMMUNICATION CONNECTION(S)
NETWORK INTERFACE
848
DISK STORAGE
824
REMOTE COMPUTER(S)
MEMORY STORAGE
844
846

FIG. 8

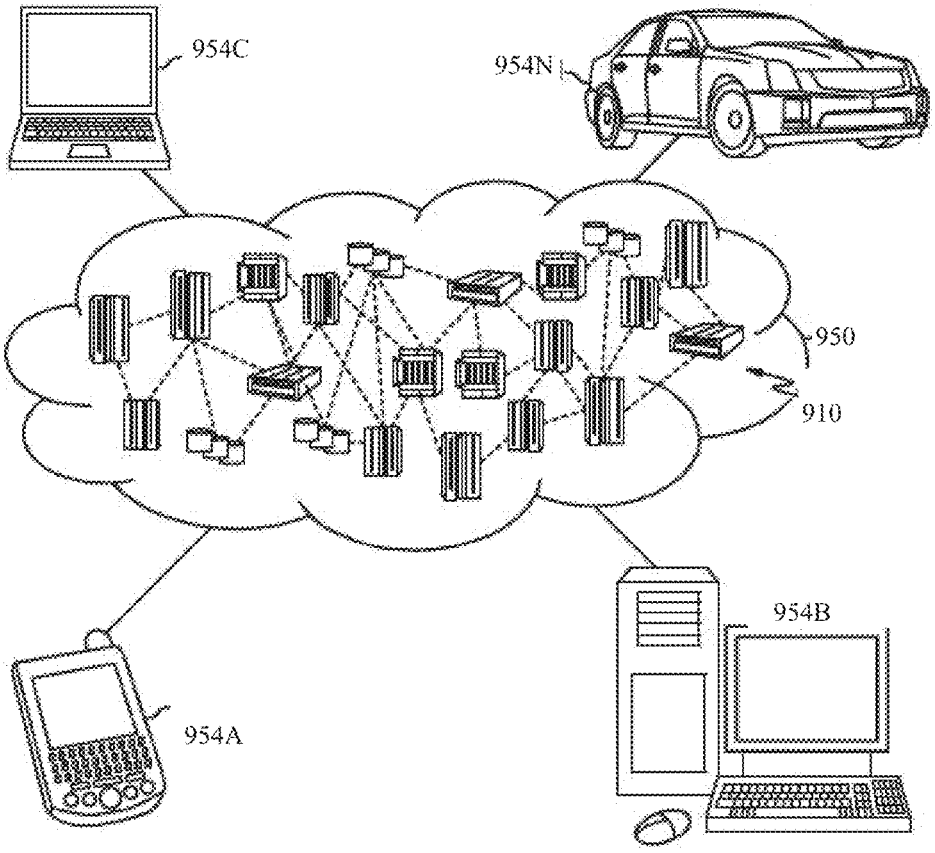
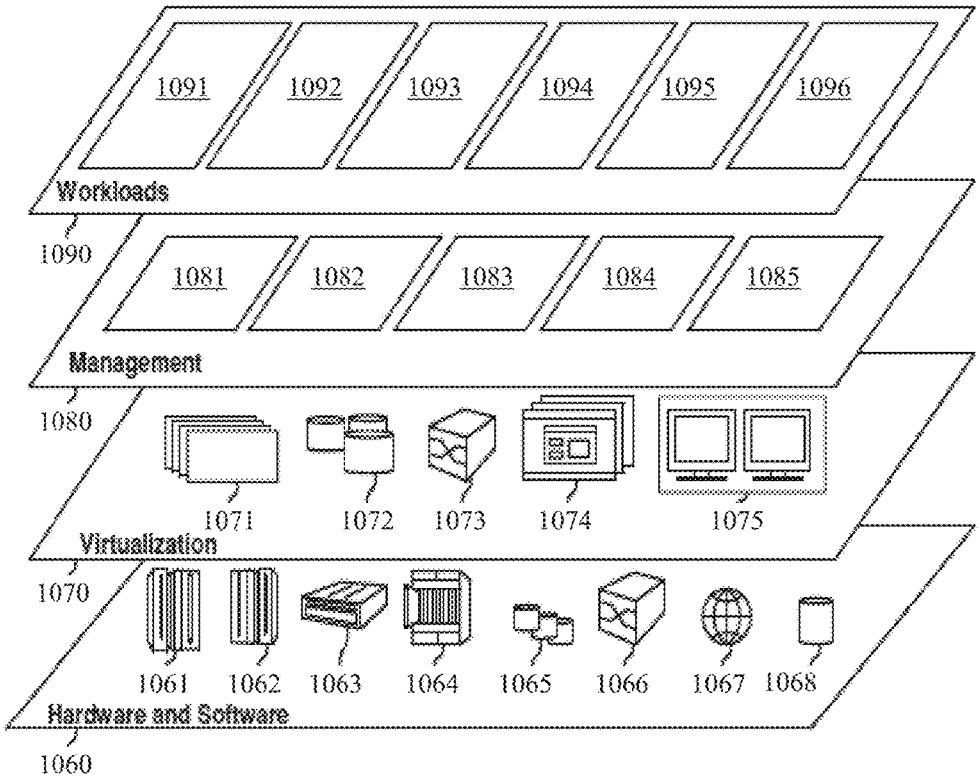


FIG. 9


1091
1092
1093
1094
1095
1096
Workloads
1090
1081
1082
1083
1084
1085
Management
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1071
1072
1073
1074
1075
Virtualization
1070
1061
1062
1063
1064
1065
1066
1067
1068
Hardware and Software
1060

FIG. 10

ACCELERATING DATA-DRIVEN SCIENTIFIC DISCOVERY

BACKGROUND

The subject disclosure relates to a system that generates directed graphs representative of a collaboration network and determines contributions of entities based on the directed graphs.

SUMMARY

The following presents a summary to provide a basic understanding of one or more embodiments of the invention. This summary is not intended to identify key or critical elements, or delineate any scope of the particular embodiments or any scope of the claims. Its sole purpose is to present concepts in a simplified form as a prelude to the more detailed description that is presented later. In one or more embodiments described herein, systems, computer-implemented methods, apparatus and/or computer program products that facilitate synchronization of processors for blockchain formation are described. The disadvantages of the references discussed above in the background have been resolved with the features disclosed herein.

According to an embodiment, a system is provided. The system can comprise a memory that stores computer executable components and a processor that executes the computer executable components stored in the memory. The components can include a graphing component that generates a directed graph representing a collaboration network between research entities associated with an outcome, wherein the directed graph comprises nodes that are associated with the research entities, and edges between the nodes representing relationships between the research entities. The components can also include a collaboration component that determines a contribution of a research entity of the research entities to the outcome based on the directed graph.

In an embodiment a computer-implemented method can be provided. The method can include generating, by a device operatively coupled to a processor, a directed graph representing a scientific research process, wherein a node of the directed graph is associated with a research entity, and an edge of the directed graph is associated with a relationship between the research entity and another research entity. The method can further include determining, by the device, a contribution amount of the research entity to a scientific result of the scientific research process based on the directed graph.

According to yet another embodiment, a computer program product to determine contribution levels is provided. The computer program product can comprise a computer readable storage medium having program instructions embodied therewith. The program instructions can be executable by a processor and cause the processor to generate a directed graph representing a collaboration network between research entities associated with an outcome, wherein the directed graph comprises nodes that are associated with the research entities, and edges between the nodes representing relationships between the research entities. The processor can also determine a contribution of a research identity of the research entities to the outcome based on the directed graph.

DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a high-level block diagram of an example, non-limiting distribution system in accordance with one or more embodiments described herein.

FIG. **2** illustrates another high-level block diagram of an example, non-limiting directed graph of a collaboration network in accordance with one or more embodiments described herein.

FIG. **3** illustrates another high-level block diagram of an example, non-limiting directed graph of a collaboration network and a blockchain ledger in accordance with one or more embodiments described herein.

FIG. **4** illustrates another high-level block diagram of an example, non-limiting blockchain ledger with transactions being verified in accordance with one or more embodiments described herein.

FIG. **5** illustrates another high-level block diagram of an example, non-limiting directed graph and blockchain ledger showing reward distributions in accordance with one or more embodiments described herein.

FIG. **6** illustrates another high-level block diagram of an example, non-limiting directed graph and blockchain ledger showing reward distributions in accordance with one or more embodiments described herein.

FIG. **7** illustrates a flow diagram of an example, non-limiting computer-implemented method for distributing rewards in accordance with one or more embodiments described herein.

FIG. **8** illustrates a block diagram of an example, non-limiting operating environment in which one or more embodiments described herein can be facilitated.

FIG. **9** illustrates a block diagram of an example, non-limiting cloud computing environment in accordance with one or more embodiments of the present invention.

FIG. **10** illustrates a block diagram of example, non-limiting abstraction model layers in accordance with one or more embodiments of the present invention.

DETAILED DESCRIPTION

The following detailed description is merely illustrative and is not intended to limit embodiments and/or application or uses of embodiments. Furthermore, there is no intention to be bound by any expressed or implied information presented in the preceding Background or Summary sections, or in the Detailed Description section.

One or more embodiments are now described with reference to the drawings, wherein like referenced numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a more thorough understanding of the one or more embodiments. It is evident, however, in various cases, that the one or more embodiments can be practiced without these specific details.

It is to be understood that although this disclosure includes a detailed description on cloud computing, implementation of the teachings recited herein are not limited to a cloud computing environment. Rather, embodiments of the present invention are capable of being implemented in conjunction with any other type of computing environment now known or later developed.

Cloud computing is a model of service delivery for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, network bandwidth, servers, processing, memory, storage, applications, virtual machines, and services) that can be rapidly provisioned and released with minimal management effort or interaction with a provider of the service. This cloud model may include at least five characteristics, at least three service models, and at least four deployment models.

Characteristics are as follows:

On-demand self-service: a cloud consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with the service's provider.

Broad network access: capabilities are available over a network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

Resource pooling: the provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to demand. There is a sense of location independence in that the consumer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter).

Rapid elasticity: capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

Measured service: cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

Service Models are as follows:

Software as a Service (SaaS): the capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based e-mail). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

Platform as a Service (PaaS): the capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including networks, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.

Infrastructure as a Service (IaaS): the capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources wherein the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls).

Deployment Models are as follows:

Private cloud: the cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on-premises or off-premises.

Community cloud: the cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on-premises or off-premises.

Public cloud: the cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.

Hybrid cloud: the cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).

A cloud computing environment is service oriented with a focus on statelessness, low coupling, modularity, and semantic interoperability. At the heart of cloud computing is an infrastructure that includes a network of interconnected nodes.

Currently, problems exist because there are limited platforms for incentivizing collaboration and sharing of time, efforts and data, as rewards are given just to entities that achieve an outcome (funding grant, monetary prize, etc). Others that may have contributed to the effort are not guaranteed to share in the reward, even though their contributions may have been important and necessary for the outcome to have been achieved.

In various embodiments disclosed herein, solutions address the above problems. For example, in various embodiments described herein, a distribution system for incentivizing and accelerating data driven scientific research is disclosed. The distribution system can track the input of various parties involved in scientific research (e.g., by the transaction ledger **114** and graphing component **106**), and when a reward, monetary or otherwise, is realized for one or more outcomes of the scientific research, the distribution system can distribute the reward among the parties that provided the input (e.g., by the distribution component **110**). The relative levels and contributions of the parties can be tracked to ensure that an equitable portioning of the reward is realized (e.g., by the collaboration component **108**). The inputs can be tracked using a transaction database (e.g., transaction ledger **114**), wherein transactions (publications, citations, patents, code sharing, data sharing, etc) can be tracked, and then a directed graph can be formed (e.g., by graphing component **106**), wherein the nodes correspond to entities, researchers, publications, and the edges correspond to relationships between the research entities (e.g., data sharing, code sharing), publications (e.g., citations). The directed graph can be analyzed to determine the relative or absolute levels of contributions from each of the entities, and the rewards can be distributed based on the contribution levels (e.g., by collaboration component **108**).

Turning now to FIG. **1**, illustrated is a high-level block diagram **100** of an example, non-limiting distribution system **102** in accordance with one or more embodiments described herein. In FIG. **1**, the distribution system **102** can include a processor **104**, a graphing component **106**, a collaboration component **108**, a distribution component **110**, a transaction component **112**, and a detection component **116**. In various embodiments, one or more of the processor **104**, the graphing component **106**, the collaboration component **108**, the distribution component **110**, the transaction component **112**, and the detection component **1116** can be electrically and/or communicatively coupled to one another to perform one or more functions of the distribution system **102**. The distribution system **102** can receive transaction and collaboration data from a transaction ledger **114**.

In some embodiments, the distribution system **102** can be a cloud based system that facilitates the distribution of rewards and recognition of various steps and outcomes in the experimental/scientific research process. In other embodiments, distribution system **102** can be based on a network or device that is performing the data collection and analysis or is communicably coupled to the system executing the program.

In an embodiment, the transaction ledger **114** can record transactions between any number of different types of entities (including, but not limited to, research groups, researchers, institutions, and other entities involved in the scientific research process and/or arena). In some embodiments, the entity can be a computerized device that is associated with one or more of a research group, researcher, institution, or the like). The transactions can include the transmission/reception of data, sharing of data, transmission/reception of computer code, the sharing of computer code and other analytical efforts, cited art references in patent documents and other contributory transactions. The transaction can include citations in one publication that cite to work performed by other researchers as catalogued in other publications. Generally the transactions can be representative of the collaboration and contributions that different groups of entities make with other groups of entities.

In an embodiment, the transaction ledger **114** can be updated explicitly, e.g., by one or more devices (that may be associated with researchers, in some embodiments) transmitting information indicative of one or more updates. The information transmitted can be a recording of the collaborations and/or contributions of the entities. In another embodiment, the transaction ledger **114** can be updated implicitly by the transaction ledger **114** analyzing citations in publications, correspondences, and etc.

In at least one example embodiment, the transaction entries can be stored in the transaction ledger **114** as a blockchain. In some embodiments, the blockchain data structure for storing transaction entries can provide stability, and/or consistency of the data. Data can be generated and stored in blocks where each block (or, in some embodiments, one or more blocks) can contain a hash and a pointer to a previous block. Thus, changing one (past) block can then typically result in changing all subsequent blocks (with high probability). This also makes the blockchain substantially tamper proof, not allowing transactions (e.g., citations) to be artificially added. Consequently, blockchain data can provide an ideal data structure for tracking collaborations, citations, data sharing, etc.

Furthermore, in various embodiments, the blockchain ledger (and therefore the transaction ledger **114**) can be distributed amongst many different entities of the distribution system **102**. Since the blockchain is public, any entity of the distribution system **102** can easily verify any transaction given that the entities are known. Verifying transactions such as citations, code sharing, or a signed collaboration contract becomes easy. A researcher (or a device associated with a researcher) could, for example, share and/or transmit the researcher entity ID on the blockchain. Other devices and/or entities generally associated with the system can verify the citations or collaborations associated with the researcher entity ID. As another example, in an event in which government run funding agency devices employ use of the blockchain (cf. instantiation B), the distribution of the funds and/or the resulting government-funded work can be verified publicly. In some embodiments, the transaction ledger **114** can also be augmented with a system or device that can manage and/or verify identity. For example, in some embodiments, the augmented transaction ledger **114** can include a sign-up system that utilizes or requires verified academic e-mail addresses.

In an embodiment, the graphing component **106** can generate the directed graph based on entries from the transaction ledger **114** and blockchain. The nodes can be associated with the different entities (e.g., devices or research groups) associated with a research chain. For instance, a node in the directed graph can represent a paper/publication, programmer, scientist, research group, institution, or patent, while the directed edges of the directed graph can represent citations, computer code sharing, data/result sharing, or prior art. In one embodiment, the graphing component **106** can generate the directed graph by tracing the transactions, and whenever an entity is involved in a transaction with another entity, the two entities can be mapped as nodes, while the edge between the nodes can represent the transaction.

In some embodiments, the collaboration component **108** can analyze the directed graph. Based on the analysis of the directed graph, the collaboration component **108** can determine contribution amounts from each entity (or, in some embodiments, one or more entities) by determining the number of transactions, incoming and outgoing relative to other entities. For instance, in one embodiment, if a paper is cited once by a researcher that receives a prize, credit, or recognition, the researcher or entity associated with the paper can be determined to have a first contribution level. If the paper is cited multiple times, then the researcher or entity can have a second contribution level higher than the first level. The contribution level can be determined for each entity (or, in some embodiments, one or more entities) in the directed graph such that reward or recognition can be credited to each entity (or, in some embodiments, one or more entities) who may have contributed an idea, time, data, insight, or other element that facilitated the resultant paper.

In some embodiments, the collaboration component **108** can determine a collaboration link between two nodes of the network by a contract agreed upon in advance by the involved entities and added to the blockchain, or by analyzing available documents or computer code (e.g., citations in a paper). This contract can be verifiable, for example, by public data, public key signature, or through other mechanisms. In an embodiment the collaboration component **108** can suggest new collaborations between one or more different entities based on an analysis of the collaboration network, and/or control incentives to increase the level of collaboration, either automatically through a defined algorithm executed by a processor of a computer or device, or via human user intervention. In an embodiment, the collaboration component **108** can also output descriptive analytics and/or aggregate statistics of the transaction network (e.g., via user interface, application programming interface (API)).

In an embodiment, the collaboration component **108** can determine the relative importance of the collaboration or contribution for an entity based on an analysis of the directed graph (e.g., number and distribution of edges from other nodes). In some embodiments, the transaction ledger **114** can comprise information indicative of comments from the entities describing the importance of the contribution, or the reliance on the collaboration as a function of the scientific outcome. In some embodiments, the collaboration component **108** can also scour the publications for comments and/or notes indicating the importance of certain citations and other contributions. For instance, the "acknowledgements" section of publications can be analyzed, a level of

importance of one or more contributions can be determined by the collaboration component. In some embodiments, the level of importance can be determined employing sentiment analysis. The importance of the contribution can then be used by the distribution component **110** to weigh the portion of the reward based on the importance of the contribution amount of the researcher.

Once a reward event (e.g., issuance or allocation of a monetary prize, recognition award, or publication, or selling of software) is triggered at an end-point of the directed graph, the distribution component **110** can automatically redistribute part of the reward throughout the network using a defined reward method based on the contribution levels determined by the collaboration component **108**. By combining information about reward events and the structure of the network, the distribution component **110** can compute an overall reward distribution. In other embodiments, the distribution component **110** can recommend a reward distribution amount to be distributed by another system or entity.

In an embodiment, the transaction component **112** can check the consistency of a new transaction before accepting the transaction and adding it to the transaction ledger **114**. The transaction consistency can be checked by matching a hash in a new entry to a hash of the previous transaction blocks to see if the hashes match.

In an embodiment, the detection component **116** can determine whether one or more entities are attempting to commit an act of deception, or artificially and misleadingly attempting to increase a contribution level relative to other entities. For instance, a research entity, when authoring a paper, can refer back to a prior work or to another entity many times unnecessarily in order to artificially increase the number of edges between the nodes to cause an appearance that one node has significant influence. The detection component **116** can track the number of citations back to self entities and to other entities and, if the number of citations, or edges formed back to other nodes is above a defined threshold, the detection component **116** can flag the contribution as potentially deceptive or otherwise inaccurate. In other embodiments, the detection component **116** can determine that no sharing of data or ideas has taken place even though references have been made to the collaboration in a research write-up or console log.

The distribution system **102** and/or the components of the distribution system **102** can employ hardware and/or software to solve problems that are highly technical in nature (e.g., use of blockchain technology, internet security, authentication, compression, big data analysis etc.), that are not abstract and that cannot be performed as a set of mental acts by a human. The distribution system **102** and/or components of the distribution system **102** can be employed to solve new problems that arise through advancements in technology (e.g., provenance of data, reliability/integrity of research which arises due to advancements in technology allowing third-party access to publications and potential tampering with electronic documents now stored in electronic database), computer networks, the Internet and/or the like.

A processor **104** can be associated with at least one of a central processor, a graphical processor, etc. In various embodiments, the processor **104** can be or include hardware, software (e.g., a set of threads, a set of processes, software in execution, etc.) or a combination of hardware and/or software that performs a computing task for machine learning (e.g., a machine learning computing task associated with received data). For example, the processor **104** can execute data analysis threads that cannot be performed by a human (e.g., are greater than the capability of a single human mind). For example, the amount of data processed, the speed of processing of the data and/or the data types processed by processor **104** over a certain period of time can be respectively greater, faster and different than the amount, speed and data type that can be processed by a single human mind over the same period of time. For example, data processed by processor **104** can be raw data (e.g., raw audio data, raw video data, raw textual data, raw numerical data, etc.) and/or compressed data (e.g., compressed audio data, compressed video data, compressed textual data, compressed numerical data, etc.) captured by one or more sensors and/or one or more computing devices. Moreover, processor **104** can be fully operational towards performing one or more other functions (e.g., fully powered on, fully executed, etc.) while also processing the above-referenced data analysis data and runtime environment data.

Turning now to FIG. **2**, illustrated is another high-level block diagram of an example, non-limiting directed graph **200** of a collaboration network in accordance with one or more embodiments described herein.

In an embodiment, the directed graph created by the graphing component **106** can have a set of nodes **202**, **204**, **206**, and **208** connected by directed edges **210**, **212**, **214**, **216**, and **218**. The nodes can correspond to entities and other events associated with the research process and can be associated with devices for researchers or organizations, researchers, programmers, patents, publications, research groups, and other similar entities, while the edges can represent the relationships between the entities. In an embodiment, the edges **210**, **212**, **214**, **216**, and **218** can be directed edges, indicating that the relationship has a flow or represents a contribution from one party to another.

As an example, if nodes **202** and **206** are associated with publications, edge **212** can represent a citation in publication associated with node **206** to another publication associated with node **202**, thus representative of a flow, or contribution from **202** to **206**. If a paper associated with node **206** receives a prize, reward, funding, or recognition, either in part or in whole, the paper associated with node **202**, and/or the authors of paper associated with node **202** can receive a portion of the reward based on their contribution, represented by edge **212**. Similarly, if paper associated with **208** is associated with an outcome or result that wins recognition, or a reward, each of the papers and authors associated with the papers at nodes **206**, **204**, and **202** can receive credit in part as well, based on the contributions represented by edges **212**, **214**, **210**, **216**, and **218**. In an embodiment, the amount of credit or reward that each paper is attributed with can be based on the contribution amounts (e.g., as determined by collaboration component **108**) and/or can vary on the number of citations, citation chain, importance of each of the citations, explicit remarks (e.g., paper at node **208** says contribution provided by paper at **204** was very important to the result, etc.).

Turning now to FIG. **3**, illustrated is another high-level block diagram **300** of an example, non-limiting directed graph **318** of a collaboration network and a blockchain ledger in accordance with one or more embodiments described herein. Repetitive description of like elements employed in other embodiments described herein is omitted for sake of brevity.

A blockchain ledger (e.g., stored in transaction ledger **114**) can comprise blocks **302** and **304** that store the transaction details associated with the graph **318** where nodes **1**, **2**, **3**, **4**, and i (**306**, **308**, **310**, **312**, and **314**) and the relationships there between are stored in block **302**. The

transactions can be stored as a list e.g., where a contribution between node **1** **306** and node **3** **310** is stored, node **2** **308** and node **3** **310**, and etc. Block **304** can represent later contributions where node i **314** contributes to node j **316**, and node **2** **308** contribute to node j **316**. Block **304** can also comprise a hash of block **1** **302** which is a mapping performed by a processor that maps data of an arbitrary size to data of fixed size, with each separate original block of data resulting in a unique hash value.

The transaction ledger blockchain can comprise a group of transaction blocks **302** and **304** that are linked to each other. Blocks are linked when hashes of previous blocks are included in the headers of subsequent blocks. Since each block can have a unique hash, a linked hash in the header is a reference back to a specific block, thus a blockchain of blocks. The master data block can comprise a first header and/or data from the data entry blocks. The header can further comprises a first time stamp representing when the data was collected or the master data block formed and/or uploaded to a public ledger. The header can also include an identifier that identifies a source of the data, and a first hash based on the data. The identifier can be a serial number associated with a research group or scientist, or can be associated with an apparatus that collects data (e.g., measurement device, etc).

Turning now to FIG. **4** illustrated is another high-level block diagram **400** of an example, non-limiting blockchain ledger with transactions being verified in accordance with one or more embodiments described herein. Repetitive description of like elements employed in other embodiments described herein is omitted for sake of brevity.

The transaction component **112** can perform checks on transaction entries before they are added to the blockchain formed by blocks **302** and **304**. For instance, proposed transaction details in transaction **402** can be compared to the transaction details in blocks **302** and **304** to see if they are consistent with the existing transaction details. Similarly, the transaction details in proposed transaction block **404** can be compared with blocks **302** and **304**, and the transaction component **112** can determine that transaction block **404** is inconsistent whereas transaction block **402** is consistent, leading to the addition of block **402** to the blockchain in the transaction ledger **114**.

Turning now to FIG. **5**, illustrated is another high-level block diagram of an example, non-limiting directed graph and blockchain ledger showing reward distributions in accordance with one or more embodiments described herein. Repetitive description of like elements employed in other embodiments described herein is omitted for sake of brevity.

If distribution component **110** determines that an outcome at node **314** has received a prize, the distribution component **110** can distribute a portion of the reward to each of the entities associated with nodes **310**, **312**, **306** and **308** that may have contributed to the award based on their contribution levels as determined by collaboration component **108**.

As an example, distribution component **110** can receive transaction block **502** from the transaction ledger that indicates that Node i **314** has received **1** reward. The collaboration component **108** can then examine the directed graph formed by the graphing component **106** form the transaction blocks **302** and **304** to determine the relative contribution levels of each of nodes **306**, **308**, **310**, and **312**.

In an embodiment, each node can adds to the ledger the amount of credit assigned to the reference. The authors or entities associated with the nodes may choose to assign credit equally among the citations, or give a higher credit to specific references. For example, a math paper may assign significant credit to a paper that derived a key inequality used in a proof. An engineering paper may assign smaller credit to papers cited in a literature survey. An area review paper may assign equal credit to all citations. In this case, only the authors of the paper need to sign the entry added to the ledger block **302**.

In an embodiment, if node **314** receives 1 credit, to determine the portion of the credit to be received by nodes **312**, **310**, **306**, and **308**, the following formula can be used where:

$$r(i \to j) = \frac{r(i)}{\alpha O(i)} \qquad \text{Eqn 1}$$

where r(i) is the reward of node **314**. If node i cites j (node **310**) registered as a transaction in the ledger block **302**, then i assigns to j a reward of r(i→j) where $\alpha>1$ is a fraction of the reward and O(i) is the number of documents cited by i. The reward that node i passes to k (node **306**) in a network is given by:

$$r(i \to k) = \sum_{j \in P(k)} \frac{r(i \to j)}{\alpha O(i)} \qquad \text{Eqn 2}$$

where P(k) is the number of publications that cite publication k (publication at node **306**). In other embodiments, the collaboration component **108** can determine the contribution level on the explicit importance as indicated by the researchers, or on other factors.

Turning now to FIG. **6**, illustrated is another block diagram **600** of an example, blockchain in accordance with one or more embodiments described herein. Repetitive description of like elements employed in other embodiments described herein is omitted for sake of brevity.

In an embodiment, the distribution system **102** can incentivize false discovery mitigation. For example, if a research group (e.g., group **602**) publishes a result of a study, the research group **602** and funding agency can incentivize other groups to duplicate the experiments to avoid false discoveries and/or confirm the results of the study. The research group can post on the transaction ledger **114** that other groups (up to a defined number) that verify the results will receive a part of the funding, and the script can be signed by both the funding agency and the research group. Once different groups (un)successfully duplicate results, research funds and credit can be transferred to the other groups. This system can allows more complex interactions between multiple agents (groups collaborating for validation), so the experiments can be shared among different groups.

The data can be shared via the ledger (e.g., stored in the blockchain) to allow the other groups (e.g., groups associated with nodes **604**, **606**, **608**, **610**, and **612**) to gather data, analyze the data, and determine whether the results achieved by group **602** are correct. The collaboration component **108** can track the performance and ledger entries by the groups **604-612**, and if the other groups arrive at conclusions either supporting or against the conclusion reached by group **602**, then the distribution component **110** can apportion part of the money, credit, recognition, or reward assigned by **602** to the groups **604-612**.

Turning now to FIG. **7**, illustrated is a flow diagram **700** of an example, non-limiting computer-implemented method for distributing rewards in accordance with one or more

embodiments described herein. Repetitive description of like elements employed in other embodiments described herein is omitted for sake of brevity.

The method can begin at **702**, where the method includes generating, by a device operatively coupled to a processor, a directed graph representing a scientific research process, where a node of the directed graph is associated with a research entity, and an edge of the directed graph is associated with a relationship between the research entity and another research entity (e.g., by graphing component **106**).

The nodes can be associated with the different entities in the research chain. For instance, a node could be a paper/publication, programmer, scientist, research group, institution, or patent, while the directed edges could be citations, code sharing, data/result sharing, or prior art.

The method can continue at **704**, where the method includes determining, by the device, a contribution amount of the research entity to a scientific result of the scientific research process based on the directed graph (e.g., by collaboration component **108**).

In an embodiment, the determining can include analyzing the directed graph and determining contribution amounts from each entity. For instance, if a paper is cited once by a researcher that receives a prize, credit, or recognition, the researcher or entity associated with the paper can be determined to have a first contribution level. If the paper is cited multiple times, then the researcher or entity can have a second contribution level higher than the first level. The contribution level can be determine for each entity in the directed graph such that reward or recognition can be credited to each entity who may have contributed an idea, time, data, insight, or other element that facilitated the outcome.

In one embodiment, the determining can include determining a collaboration link between two nodes of the network by a contract pre-agreed by the involved parties and added to the blockchain, or by analyzing available documents/code (e.g., citations in a paper). This contract can be verifiable, for example, by publicly data, public key signature, or through other mechanisms. In an embodiment new collaborations can be suggested based on an analysis of the collaboration network, and control incentives to increase the level of collaboration, either automatically through a pre-programmed algorithm, or via human user intervention. In an embodiment descriptive analytics can be outputted and/or aggregate statistics of the transaction network (e.g., via user interface, API)

For simplicity of explanation, the computer-implemented methodologies are depicted and described as a series of acts. It is to be understood and appreciated that the subject innovation is not limited by the acts illustrated and/or by the order of acts, for example acts can occur in various orders and/or concurrently, and with other acts not presented and described herein. Furthermore, not all illustrated acts can be required to implement the computer-implemented methodologies in accordance with the disclosed subject matter. In addition, those skilled in the art will understand and appreciate that the computer-implemented methodologies could alternatively be represented as a series of interrelated states via a state diagram or events. Additionally, it should be further appreciated that the computer-implemented methodologies disclosed hereinafter and throughout this specification are capable of being stored on an article of manufacture to facilitate transporting and transferring such computer-implemented methodologies to computers. The term article of manufacture, as used herein, is intended to encompass a computer program accessible from any computer-readable device or storage media.

Moreover, because configuration of data packet(s) and/or communication between processing components and/or an assignment component is established from a combination of electrical and mechanical components and circuitry, a human is unable to replicate or perform the subject data packet configuration and/or the subject communication between processing components and/or an assignment component. For example, a human is unable to generate data for transmission over a wired network and/or a wireless network between processing components and/or an assignment component, etc. Moreover, a human is unable to packetize data that can include a sequence of bits corresponding to information generated during a machine learning process (e.g., a semantic labeling process), transmit data that can include a sequence of bits corresponding to information generated during a machine learning process (e.g., a semantic labeling process), etc.

In order to provide a context for the various aspects of the disclosed subject matter, FIG. **8** as well as the following discussion are intended to provide a general description of a suitable environment in which the various aspects of the disclosed subject matter can be implemented. FIG. **8** illustrates a block diagram of an example, non-limiting operating environment in which one or more embodiments described herein can be facilitated. Repetitive description of like elements employed in other embodiments described herein is omitted for sake of brevity. With reference to FIG. **8**, a suitable operating environment **800** for implementing various aspects of this disclosure can also include a computer **812**. The computer **812** can also include a processing unit **814**, a system memory **816**, and a system bus **818**. The system bus **818** couples system components including, but not limited to, the system memory **816** to the processing unit **814**. The processing unit **814** can be any of various available processors. Dual microprocessors and other multiprocessor architectures also can be employed as the processing unit **814**. The system bus **818** can be any of several types of bus structure(s) including the memory bus or memory controller, a peripheral bus or external bus, and/or a local bus using any variety of available bus architectures including, but not limited to, Industrial Standard Architecture (ISA), Micro-Channel Architecture (MSA), Extended ISA (EISA), Intelligent Drive Electronics (IDE), VESA Local Bus (VLB), Peripheral Component Interconnect (PCI), Card Bus, Universal Serial Bus (USB), Advanced Graphics Port (AGP), Firewire (IEEE 1394), and Small Computer Systems Interface (SCSI). The system memory **816** can also include volatile memory **820** and nonvolatile memory **822**. The basic input/output system (BIOS), containing the basic routines to transfer information between elements within the computer **812**, such as during start-up, is stored in nonvolatile memory **822**. By way of illustration, and not limitation, nonvolatile memory **822** can include read only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), flash memory, or nonvolatile random access memory (RAM) (e.g., ferroelectric RAM (FeRAM). Volatile memory **820** can also include random access memory (RAM), which acts as external cache memory. By way of illustration and not limitation, RAM is available in many forms such as static RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM),

direct Rambus RAM (DRRAM), direct Rambus dynamic RAM (DRDRAM), and Rambus dynamic RAM.

Computer **812** can also include removable/non-removable, volatile/non-volatile computer storage media. FIG. **8** illustrates, for example, a disk storage **824**. Disk storage **824** can also include, but is not limited to, devices like a magnetic disk drive, floppy disk drive, tape drive, Jazz drive, Zip drive, LS-100 drive, flash memory card, or memory stick. The disk storage **824** also can include storage media separately or in combination with other storage media including, but not limited to, an optical disk drive such as a compact disk ROM device (CD-ROM), CD recordable drive (CD-R Drive), CD rewritable drive (CD-RW Drive) or a digital versatile disk ROM drive (DVD-ROM). To facilitate connection of the disk storage **824** to the system bus **818**, a removable or non-removable interface is typically used, such as interface **826**. FIG. **8** also depicts software that acts as an intermediary between users and the basic computer resources described in the suitable operating environment **800**. Such software can also include, for example, an operating system **828**. Operating system **828**, which can be stored on disk storage **824**, acts to control and allocate resources of the computer **812**. System applications **830** take advantage of the management of resources by operating system **828** through program modules **832** and program data **834**, e.g., stored either in system memory **816** or on disk storage **824**. It is to be appreciated that this disclosure can be implemented with various operating systems or combinations of operating systems. An entity enters commands or information into the computer **812** through input device(s) **836**. Input devices **836** include, but are not limited to, a pointing device such as a mouse, trackball, stylus, touch pad, keyboard, microphone, joystick, game pad, satellite dish, scanner, TV tuner card, digital camera, digital video camera, web camera, and the like. These and other input devices connect to the processing unit **814** through the system bus **818** via interface port(s) **838**. Interface port(s) **838** include, for example, a serial port, a parallel port, a game port, and a universal serial bus (USB). Output device(s) **840** use some of the same type of ports as input device(s) **836**. Thus, for example, a USB port can be used to provide input to computer **812**, and to output information from computer **812** to an output device **840**. Output adapter **842** is provided to illustrate that there are some output devices **840** like monitors, speakers, and printers, among other output devices **840**, which require special adapters. The output adapters **842** include, by way of illustration and not limitation, video and sound cards that provide a means of connection between the output device **840** and the system bus **818**. It should be noted that other devices and/or systems of devices provide both input and output capabilities such as remote computer(s) **844**.

Computer **812** can operate in a networked environment using logical connections to one or more remote computers, such as remote computer(s) **844**. The remote computer(s) **844** can be a computer, a server, a router, a network PC, a workstation, a microprocessor based appliance, a peer device or other common network node and the like, and typically can also include many or all of the elements described relative to computer **812**. For purposes of brevity, only a memory storage device **846** is illustrated with remote computer(s) **844**. Remote computer(s) **844** is logically connected to computer **812** through a network interface **848** and then physically connected via communication connection **850**. Network interface **848** encompasses wire and/or wireless communication networks such as local-area networks (LAN), wide-area networks (WAN), cellular networks, etc. LAN technologies include Fiber Distributed Data Interface (FDDI), Copper Distributed Data Interface (CDDI), Ethernet, Token Ring and the like. WAN technologies include, but are not limited to, point-to-point links, circuit switching networks like Integrated Services Digital Networks (ISDN) and variations thereon, packet switching networks, and Digital Subscriber Lines (DSL). Communication connection(s) **850** refers to the hardware/software employed to connect the network interface **848** to the system bus **818**. While communication connection **850** is shown for illustrative clarity inside computer **812**, it can also be external to computer **812**. The hardware/software for connection to the network interface **848** can also include, for exemplary purposes only, internal and external technologies such as, modems including regular telephone grade modems, cable modems and DSL modems, ISDN adapters, and Ethernet cards.

Referring now to FIG. **9**, an illustrative cloud computing environment **950** is depicted. As shown, cloud computing environment **950** includes one or more cloud computing nodes **910** with which local computing devices used by cloud consumers, such as, for example, personal digital assistant (PDA) or cellular telephone **954**A, desktop computer **954**B, laptop computer **954**C, and/or automobile computer system **954**N may communicate. Nodes **910** may communicate with one another. They may be grouped (not shown) physically or virtually, in one or more networks, such as Private, Community, Public, or Hybrid clouds as described hereinabove, or a combination thereof. This allows cloud computing environment **950** to offer infrastructure, platforms and/or software as services for which a cloud consumer does not need to maintain resources on a local computing device. It is understood that the types of computing devices **954**A-N shown in FIG. **9** are intended to be illustrative only and that computing nodes **910** and cloud computing environment **950** can communicate with any type of computerized device over any type of network and/or network addressable connection (e.g., using a web browser).

Referring now to FIG. **10**, a set of functional abstraction layers provided by cloud computing environment **950** (FIG. **9**) is shown. It should be understood in advance that the components, layers, and functions shown in FIG. **10** are intended to be illustrative only and embodiments of the invention are not limited thereto. As depicted, the following layers and corresponding functions are provided:

Hardware and software layer **1060** includes hardware and software components. Examples of hardware components include: mainframes **1061**; RISC (Reduced Instruction Set Computer) architecture based servers **1062**; servers **1063**; blade servers **1064**; storage devices **1065**; and networks and networking components **1066**. In some embodiments, software components include network application server software **1067** and database software **1068**.

Virtualization layer **1070** provides an abstraction layer from which the following examples of virtual entities may be provided: virtual servers **1071**; virtual storage **1072**; virtual networks **1073**, including virtual private networks; virtual applications and operating systems **1074**; and virtual clients **1075**.

In one example, management layer **1080** may provide the functions described below. Resource provisioning **1081** provides dynamic procurement of computing resources and other resources that are utilized to perform tasks within the cloud computing environment. Metering and Pricing **1082** provide cost tracking as resources are utilized within the cloud computing environment, and billing or invoicing for consumption of these resources. In one example, these

resources may include application software licenses. Security provides identity verification for cloud consumers and tasks, as well as protection for data and other resources. User portal **1083** provides access to the cloud computing environment for consumers and system administrators. Service level management **1084** provides cloud computing resource allocation and management such that required service levels are met. Service Level Agreement (SLA) planning and fulfillment **1085** provide pre-arrangement for, and procurement of, cloud computing resources for which a future requirement is anticipated in accordance with an SLA.

Workloads layer **1090** provides examples of functionality for which the cloud computing environment may be utilized. Non-limiting examples of workloads and functions which may be provided from this layer include: mapping and navigation **1091**; software development and lifecycle management **1092**; virtual classroom education delivery **1093**; data analytics processing **1094**; transaction processing **1095**; and transaction model software **1096**.

The present invention may be a system, a method, an apparatus and/or a computer program product at any possible technical detail level of integration. The computer program product can include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention. The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium can be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium can also include the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network. The network can comprise copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device. Computer readable program instructions for carrying out operations of the present invention can be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, configuration data for integrated circuitry, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Smalltalk, C++, or the like, and procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions can execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer can be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection can be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) can execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present invention.

Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions. These computer readable program instructions can be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions can also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks. The computer readable program instructions can also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational acts to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams can represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the

functions noted in the blocks can occur out of the order noted in the Figures. For example, two blocks shown in succession can, in fact, be executed substantially concurrently, or the blocks can sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

While the subject matter has been described above in the general context of computer-executable instructions of a computer program product that runs on a computer and/or computers, those skilled in the art will recognize that this disclosure also can or can be implemented in combination with other program modules. Generally, program modules include routines, programs, components, data structures, etc. that perform particular tasks and/or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the inventive computer-implemented methods can be practiced with other computer system configurations, including single-processor or multiprocessor computer systems, mini-computing devices, mainframe computers, as well as computers, hand-held computing devices (e.g., PDA, phone), microprocessor-based or programmable consumer or industrial electronics, and the like. The illustrated aspects can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. However, some, if not all aspects of this disclosure can be practiced on stand-alone computers. In a distributed computing environment, program modules can be located in both local and remote memory storage devices.

As used in this application, the terms "component," "system," "platform," "interface," and the like, can refer to and/or can include a computer-related entity or an entity related to an operational machine with one or more specific functionalities. The entities disclosed herein can be either hardware, a combination of hardware and software, software, or software in execution. For example, a component can be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on a server and the server can be a component. One or more components can reside within a process and/or thread of execution and a component can be localized on one computer and/or distributed between two or more computers. In another example, respective components can execute from various computer readable media having various data structures stored thereon. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network such as the Internet with other systems via the signal). As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, which is operated by a software or firmware application executed by a processor. In such a case, the processor can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts, wherein the electronic components can include a processor or other means to execute software or firmware that confers at least in part the functionality of the electronic components. In an aspect, a component can emulate an electronic component via a virtual machine, e.g., within a cloud computing system.

In addition, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from context, "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then "X employs A or B" is satisfied under any of the foregoing instances. Moreover, articles "a" and "an" as used in the subject specification and annexed drawings should generally be construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form. As used herein, the terms "example" and/or "exemplary" are utilized to mean serving as an example, instance, or illustration. For the avoidance of doubt, the subject matter disclosed herein is not limited by such examples. In addition, any aspect or design described herein as an "example" and/or "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs, nor is it meant to preclude equivalent exemplary structures and techniques known to those of ordinary skill in the art.

As it is employed in the subject specification, the term "processor" can refer to substantially any computing processing unit or device comprising, but not limited to, single-core processors; single-processors with software multithread execution capability; multi-core processors; multi-core processors with software multithread execution capability; multi-core processors with hardware multithread technology; parallel platforms; and parallel platforms with distributed shared memory. Additionally, a processor can refer to an integrated circuit, an application specific integrated circuit (ASIC), a digital signal processor (DSP), a field programmable gate array (FPGA), a programmable logic controller (PLC), a complex programmable logic device (CPLD), a discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. Further, processors can exploit nano-scale architectures such as, but not limited to, molecular and quantum-dot based transistors, switches and gates, in order to optimize space usage or enhance performance of user equipment. A processor can also be implemented as a combination of computing processing units. In this disclosure, terms such as "store," "storage," "data store," data storage," "database," and substantially any other information storage component relevant to operation and functionality of a component are utilized to refer to "memory components," entities embodied in a "memory," or components comprising a memory. It is to be appreciated that memory and/or memory components described herein can be either volatile memory or nonvolatile memory, or can include both volatile and nonvolatile memory. By way of illustration, and not limitation, nonvolatile memory can include read only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable ROM (EEPROM), flash memory, or nonvolatile random access memory (RAM) (e.g., ferroelectric RAM (FeRAM). Volatile memory can include RAM, which can act as external cache memory, for example. By way of illustration and not limitation, RAM is available in many forms such as synchronous RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM),

Synchlink DRAM (SLDRAM), direct Rambus RAM (DRRAM), direct Rambus dynamic RAM (DRDRAM), and Rambus dynamic RAM (RDRAM). Additionally, the disclosed memory components of systems or computer-implemented methods herein are intended to include, without being limited to including, these and any other suitable types of memory.

What has been described above include mere examples of systems and computer-implemented methods. It is, of course, not possible to describe every conceivable combination of components or computer-implemented methods for purposes of describing this disclosure, but one of ordinary skill in the art can recognize that many further combinations and permutations of this disclosure are possible. Furthermore, to the extent that the terms "includes," "has," "possesses," and the like are used in the detailed description, claims, appendices and drawings such terms are intended to be inclusive in a manner similar to the term "comprising" as "comprising" is interpreted when employed as a transitional word in a claim. The descriptions of the various embodiments have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments. The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

What is claimed is:

1. A system, comprising:

a memory that stores computer executable components; and

a processor that executes the computer executable components stored in the memory, wherein the computer executable components comprise:

a graphing component that generates a directed graph representing a collaboration network between research entities associated with an outcome, wherein the directed graph comprises nodes that are associated with the research entities, and edges between the nodes representing relationships between the research entities; and

a collaboration component that determines a contribution of a research entity of the research entities to the outcome based on the directed graph, wherein an entry of entries in a distributed ledger generated by the graphing component comprises transaction details between the research entities, and a description of a collaboration level between the research entities, wherein the collaboration component determines the contribution of the research entity based on an acknowledgement of the contribution from a research entity downstream in the directed graph, wherein the acknowledgement of the contribution is located in a section of a publication written by the research entity.

2. The system of claim **1**, wherein the graphing component generates the directed graph based on the entries in the distributed ledger.

3. The system of claim **2**, wherein the distributed ledger is a blockchain ledger.

4. The system of claim **2**, wherein the computer executable components further comprise:

a transaction component that determines whether transactions in the distributed ledger are consistent by comparing hashes of a subsequent transaction to a previous transaction.

5. The system of claim **1**, wherein nodes of the directed graph are publications associated with the research entities and the edges of the directed graph are citations.

6. The system of claim **1**, wherein the collaboration component determines the contribution of the research entity based on a distribution of edges throughout the directed graph.

7. The system of claim **1**, wherein the computer executable components further comprise

a distribution component that determines information indicative of a reward distributed to research entities based on the contribution of the research entity relative to a total contribution of each of the research entities.

8. The system of claim **1**, wherein the computer executable components further comprise:

a detection component that analyses the directed graph to determine whether the research entity is improperly increasing a number of edges connected to a node associated with the research entity.

9. A computer program product to determine contribution levels, the computer program product comprising a computer readable storage medium having program instructions embodied therewith, the program instructions executable by a processor to cause the processor to:

generate a directed graph representing a collaboration network between research entities associated with an outcome, wherein the directed graph comprises nodes that are associated with the research entities, wherein an entry of entries in a distributed ledger generated by a graphing component comprises transaction details between the research entities, and edges between the nodes representing relationships between the research entities; and

determine a contribution of a research identity of the research entities to the outcome based on the directed graph, wherein an entry of entries in a distributed ledger generated by the graphing component comprises a description of a collaboration level between the research entities, wherein the contribution is determined based on an acknowledgement of the contribution from a research entity downstream in the directed graph, and wherein the acknowledgement of the contribution is located in a section of a publication written by the research entity.

10. The computer program product of claim **9**, wherein the generating comprises generating the directed graph based on the entries in the distributed ledger.

11. The computer program product of claim **10**, wherein the distributed ledger is a blockchain ledger.

12. A system, comprising:

a memory that stores computer executable components; and

a processor that executes the computer executable components stored in the memory, wherein the computer executable components comprise:

a graphing component that generates a directed graph representing a collaboration network between research entities associated with an outcome, wherein the directed graph comprises nodes that are associated with the research entities, wherein an entry of entries in a distributed ledger generated by the graphing component comprises transaction details between the research entities, and wherein an

entry of entries in a distributed ledger generated by the graphing component comprises a collaboration level between the research entities; and

a collaboration component that determines a contribution of the research entity based on an acknowledgement of the contribution from a research entity downstream in the directed graph, wherein the acknowledgement of the contribution is located in a publication associated with the research entity.

13. The system of claim **12**, wherein the distributed ledger comprises a blockchain ledger.

14. The system of claim **12**, wherein the computer executable components further comprise:

a transaction component that determines whether transactions in the distributed ledger are consistent by comparing hashes of a subsequent transaction to a previous transaction.

15. The system of claim **12**, wherein nodes of the directed graph represent publications associated with the research entities and the edges of the directed graph are citations.

16. The system of claim **12**, wherein the computer executable components further comprise:

a collaboration component that determines a contribution of the research entity based on a distribution of edges throughout the directed graph.

17. The system of claim **12**, wherein the computer executable components further comprise

a distribution component that determines information indicative of a reward distributed to the research entities based on a contribution of the research entity relative to a total contribution of each of the research entities.

18. The system of claim **12**, wherein the computer executable components further comprise:

a detection component that analyses the directed graph to determine whether the research entity is improperly increasing a number of edges connected to a node associated with the research entity.

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