Call for Proposals

Data Management and Process

HIRP OPEN 2017

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Application Deadline: 09:00 A.M., 16th June, 2017 (Beijing Standard Time, GMT+8).

If you have any questions or suggestions about HIRP OPEN 2017, please send Email (innovation@huawei.com). We will reply as soon as possible.

Catalog

HIRPO2017170501 ~ HIRPO2017170506

1 Theme: Data Management and Processing

2 Subject: The Exploitation of Key Technologies in Graph Data Management System

3 Background

In recent years, there has been a sharp surge in the availability of graph data (***graph*** *and* ***network*** *are interchangeable in this proposal*). Ranging from financial transactional networks, digital footprint of online social networks (e.g. Facebook, LinkedIn), social media (e.g. Youtube, Flickr, Blogs) to biological networks (e.g. Protein-Protein interaction). Analysts, sociologists, computer scientists and others are interested in exploring the nature of relationships, patterns, occurrence of communities etc. to understand certain types of behaviors or predict events amongst many other objectives. Appropriately, many data management tools and libraries have been developed to conduct data query and network analysis on graph datasets (Neo4J, Titan, GraphX, Giraph, etc.). Most of the works in current graph data manage system have primarily focused on examination of static network/graph snapshots. In this project we are interested to explore the key technologies in graph data manage system, such as management of temporal graph data, spatiotemporal graph data, streaming graph data, etc. (**Just name a few examples below, welcome to propose any key/killer technologies that you think maybe critical to current graph DB system**).

- **Temporal Graph Data Management**: Understand nature of graph changes over time is extremely helpful in many real-world applications. For example, fraud credit cards detection (银行业务场景中可疑行为检测) is one of the top interested behaviors in large financial institutions due to the huge financial loss. To detect such malicious behavior in large scale financial transaction network, we need to consider both graph structure and property over time (evolving graph over time, Figure 1.), because fraudsters may behavior like regular customers in most of the time, and one day the malicious “busts out”,

maxing out all their credit lines, bringing all of their balances to zero using fake checks and disappear. We may miss such credit card illegal behaviors if only focus on static transaction network/graph and graph temporal information are overlooked.

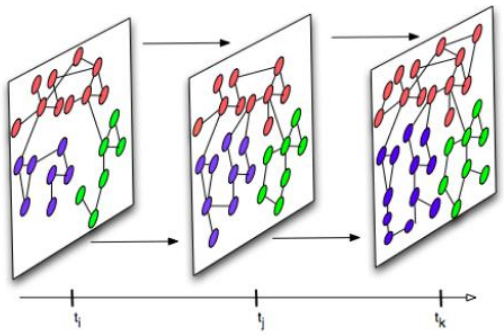
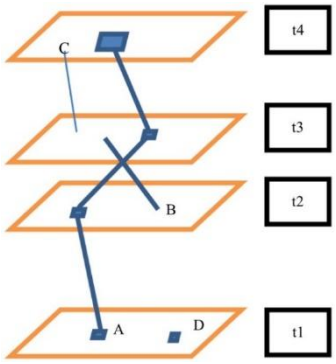


Figure 1. Evolving Graph over time (Temporal Graph)

- **Spatiotemporal graph management**: On the other hand, applications such as smart city with widely build sensors (cameras, sensors, etc), safe city, and Geographic Information Systems (GIS), need to efficiently store and process real world spatial data. The values are undoubtedly established through their dynamic contributions in a wide range decision-making sectors including safe city, smart city applications, natural resources, energy, environment, trade, urban planning, natural hazard, etc. For example, customers in safe city scenario (平安城市业务场景中) are very interested to detect the suspicious subgroup of people, who always appear together at the similar location over time, such as catch the same train/bus/flight, live in the same hotel over similar time periods. Such suspicious behavior activities can only be discovered by analyzing spatiotemporal graph, which jointly consider both the temporal and spatial graph information.

Graph data objects in real world have attributes related to both space and time and managing them using existing RDBMS is complex and in-efficient, because these objects which show spatiotemporal behavior are multi-dimensional in nature. For example an object changing its geometry over its course, exhibits both spatial as well as temporal qualities, as it can change its shape at different points in time, as well as the location of the object. There is a need to store these objects and view it the same way it was at any particular point in time (an example is provided in Figure 2.). The main challenge here is

that, traditional database management systems are geared towards providing efficient support for simple objects which have just a discrete values attached to them However, in the case of spatiotemporal objects, in addition to the value of objects, the time of occurrence and the spatial location also need to be considered, hence coming up with an efficient data management system which will consider these different dimensions into account is very much important.



- Figure 2. Spatiotemporal Graph Data Management

- **Streaming graph data management**: Streaming graph data has become more and more popular and important in past few years with the development of Internet of Things (IOT). For example, in smart traffic application scenario, the sensors that widely build in cars, sensors in road intersections have enable the efficient operation of traffic lights, use better data and automated algorithms to keep traffic flowing more smoothly. These sensor data generated in IOT has following attributes: (1) Data generated from nearby cars, and road intersections compose a local connected graph, which can help us to discover co-occurrence cars (同行问题) in smart city scenario, and other interesting patterns. (2) Data generated are streaming data, which generated in continuous real-time. Which leads us the challenge of data synchronization with multi-sensor data, analyzing streaming data for interested behavior, etc.

we are interested in explore key technologies in graph data management because many real world applications need to store, query, and analyze graph data in Graph data management system.

Before we move to the section of our interested key technologies, we list the **key pain points of current Huawei graph management solution** below:

- In terms of high performance on storage:
  - Data Import: Dynamic relation update should satisfy requirements of both efficiency and consistency
  - Scale out problem: Need to support graph with tens of billions nodes, and thousands of billions edges
  - Skewness of Graph data: Need efficiently partition graph nodes and edges in distributed environment
- Large amount of graph queries
  - Should support multi-hops relation search: interactive relation search in 3 second (current search over 3 hops needs more than 20 seconds)
  - Efficient graph Index to satisfy the interactive relation search in 3 seconds
- Unable to handle streaming graph data

We are interested to investigate the key technologies of graph data management system, in order to solve the problems from Huawei customers' requests, such as the challenges in the applications of safe city (平安城市) and financial institution (银行金融业务场景). We will introduce these highlighted key technologies in next section in details.

4 Scope

This proposal lists 6 tasks to build a project context. We also welcome collaborator to propose other ideas that they think are critical and important to graph DB.

4.1 Advanced Partitioning Technology for Large Graph, has the capability to handle incremental computation (HIRPO2017170501)

Graph partition is widely used in social network analysis with minimum cut type of approaches. However, in large scale graph data management system, it needs to efficiently store, query and analyze the evolving graph. Such system needs to have following attributes:

- Besides minimizing the cutting (communication) cost between partitioned subgroups, the partitioned subgroups should also have roughly equal graph size to

achieve the workload balance target, as we are interested in paralleled distributed environment and each subgroup may be assigned to a single machine

- The workload of user operations, such as queries and analysis may change over time. We need a dynamic graph partition solution, which has the capability to dynamically adjust the graph partition assignments based on the user workload changes.
- The graph partition technology should has the capability to handle the streaming graph data.
- The graph partition technology should consider not only the graph structure, but also spatial and temporal information on the graph, with the purpose to make the graph query and analytics in both an effective and efficient way.

4.2 Graph Indexing in Graph Data Management System (HIRPO2017170502)

In the core of many graph-related applications, lies a common and critical problem: *how to efficiently process graph queries and retrieve related graphs*. In some cases, the success of an application directly relies on the efficiency of the query processing system. The classical graph query problem can be described as follows: *Given a graph database* $D = \{g_1, g_2, \dots, g_n\}$ *and a graph query q, find all the graphs in which q is a subgraph*. It is inefficient to perform a sequential scan on the graph database and check whether q is a subgraph of g_i. Sequential scan is very costly because one has to not only access the whole graph database but also check subgraph isomorphism which is a NP-complete.

- Exploring graph indices technologies to help processing both graph isomorphism and similarity queries, validate by comparing against state of arts. Validation criterion include the speed of answering graph queries, etc.
- Indexing technologies need to work for static graph, dynamic streaming graph data, and spatiotemporal graph data, also has the capability to handle incremental graph update（add new node, edge, delete old node, edge, etc.）

4.3 Data Analytics Technologies for Large Scale Graph Data Management System (HIRPO2017170503)

For better utilize the stored graph data, we are interested to have following characteristics

in our graph data management system.

- **Predictive Analytics**: identifying the categorical information or estimating the relationships among variables. Widely use in fraud transaction detection in financial/communication transaction network/graph (电信/金融欺诈等应用场景), malicious detection in social graph or network traffic network (智慧城市，平安城市，网络攻击检测等应用场景).
- **Sub-graph Mining and Tracking:** discovering interesting sub-graphs from large scale graph by considering three sources of information: (1) network connectivity and node attributes (2) temporal network changes over time (3) spatial relations among nodes and links in network. These subgroup mining and tracking tasks include:
  - Given a sub-graph as a query, discover similar sub-graphs in a ranking list from the whole graph, which ranked based on the above listed three sources of information (社团相似性分析). Track discovered sub-graph changes over time and locations.
  - Discover the interested sub-groups from the whole graph, the interesting sub-groups may include co-occurrence nodes in a similar connectivity pattern over time and across different spatial locations (社会关系中同行同住、同上网、通话联系、社团发现问题)
  - Identify the bridge or strongest node from the large scale graph, which may reflect the most impact or critical person in social knowledge graph. (社会关系中核心人物推荐等)
  - A visualization technology may be involved to represent above discovery and tracking results

4.4 Graph Data Management System with Active Analytics Capabilities (HIRPO2017170504)

Existing graph data management system has the drawbacks of (1) assuming user has a clear target of graph data analysis targets beforehand, this assumption not always true especially in large scale graph data (2) the graph analysis operations usually happen at

different machine/cluster of machines, which may involve heave I/O and security issues. To overcome such drawbacks, we would like to have following characteristics in our spatiotemporal graph data management system:

- Graph Data Analytics work on the same machine/cluster of machines where the data locates
- Has the capability to discover unknown knowledge from graph data to surprise user with idle system resources, such knowledge include predictive/association/cluster relations, etc.
- Graph Data Analytics should consider not only the data stored in data management system, but also the user behaviors, such as diagram of DB, user query logs, etc., to understand user intention and needs. To better provide the personalized/customized services to meet customer needs

4.5 Large Scale Graph Data Management System Acceleration with GPU and Machine Learning (HIRPO2017170505)

Many real-world applications need to manage data at a very large scale. For example, Baidu needs to process around 100 PB per day, update 10 Billion webpages daily, and handles over a PB of logs updates every 24 hours. This scale of requirement put existing technologies in both hardware and software to a bottleneck. To solve this problem, we are interested in exploring the key technologies in both software and hardware in accelerating large scale spatiotemporal data management system, include:

- Exploring the state of arts machine learning technologies, such as deep learning, in DB acceleration, such as graph query optimization, workload management/optimization, etc.
- GPU/FPGA like hardware efforts to accelerating graph management at Scale

4.6 Graph DB Industry Benchmark (HIRPO2017170506)

Given there is no serious or completed work for graph database benchmark, the purpose of this project is to develop an industry standard benchmark for graph database analytics, not for internal evaluation purpose. The objective of this project is to help Huawei lead or be involved with the design of a potential end-to-end benchmark for graph database

analytics. For this industrial standard graph database benchmark, need to cover simulated industrial scenarios and demonstrate:

- Data model: logical & physical data model and data generation
- Workload queries specification
- Implementation of benchmark on VoltGB and/or other graph engines
- Point query over large scale dataset
- Data manipulation at scale out cluster
- Highly paralleled computation

The goal of this benchmark is become an industrial standard for Graph DB. Similar to TPC benchmark for Relational Database Management System (RDBMS).

5 Expected Outcome and Deliverables

For each research topic, the following deliverables are required

1) Software Deliverables

<table>
<tr><th>No.</th><th>Software Component</th><th colspan="2">Remark</th></tr>
<tr><td>1</td><td>Proof of Concept (PoC) of the new solution and technique</td><td colspan="2">Can be compiled and executed to show the advantage of the new idea</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Benchmark test code of the new solution and technique</td><td colspan="2">Can be used to build the environment of testing and reproduce the benchmark result, performance need to be validated by real-world graph data sets widely used in the field, including but not limit to Wiki-pedia, Wiki-Talk, Web-Google, Live-Journal, Twitter, Synthetic (http://snap.stanford.edu/data/index.html)</td></tr>
<tr><td>Topic</td><td>Criteria</td></tr>
<tr><td>Advanced Partitioning Technology for Large Graph</td><td>Edge cut ratio (ECR), Job execution time (JET), Standard Deviation of running time (SDT) can be improved by 20%</td></tr>
</table>

2) Non-software Deliverables

No.	Content	Quantity
1	Survey of existing related solutions and techniques	1
2	Design document of the new solution and technique	1
3	Benchmark testing report of the new solution and technique	1
4	Publication	1
5	Idea	1

6 Acceptance Criteria

The success of the project will be proved by the research group working with Huawei's Acceptance Team to evaluate the proposed techniques against the benchmark data specified by Huawei.

Following each evaluation, the Acceptance Team of Huawei will decide on formal acceptance of the relevant deliverables and will notify the research team accordingly. More specifically,

- The research team will deliver methods, algorithms, design, implementation and experimental results for our techniques, so that the techniques can be evaluated with public available graph data mentioned in section 6, and lead to an extensive performance report
- The research team will collaborate with researchers and developers of Huawei for testing and evaluating our techniques at Huawei, and propose solutions to problems encountered at Huawei US R&D

The acceptance criterion are defined in section 6 – "*Benchmark test code of the new solution and technique*", or collaborators feel free to propose reasonable targets.

6.1 Acceptance Environment：

The Project Manager of Huawei will organize the Acceptance Team to review the Reports, and prepare experimental data for the research team. The research team will then set up the testing environment on public environment, e.g., Postgres-XC project (PostgreSQL license) and Greenplum Database project, etc., to evaluate the techniques against the corresponding benchmark.

6.2 Enablement Workshop:

Both parties would jointly host enablement workshop, preferably face to face, at the beginning of the project, as well as during the project repeat every six months to keep both parties on the same page.

6.2.1 For the kick-off enablement workshop at the beginning of the project:

- Huawei team should come up with a vision document which describes the claim of business value, the main capabilities/functions, the architectural design, the validation/evaluation plan, and the integration plan.
- The university research team and Huawei team should formally establish the project team with the resource identified and committed.
- The project plan should be created by both parties based on committed resource.

6.2.2 For the repeat enablement workshop during the project:

- Both parties to synch on the same page with the update of the progress
- Functional integration and validation at that stage
- Make changes, if any, to the project plan to adapt to the dynamics of the project.

7 Phased Project Plan

The default length of project development plan for each of the above listed 6 key technologies is 1 year, but feel free to propose longer plan, say 2 year, if needed with defined intermediate milestone targets.

8 Budget

The budget should be provided according to your plan, all the fees should be reasonable and with details. It could be provided according to the table below:

Budget Breakdown Template.xlsx

9 Other Information

We listed 6 key technologies in section 6 to explore the research collaboration opportunities, we welcome research collaborator to apply any single one or multiple technologies.

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HIRPO2017170507 ~ HIRPO2017170511

1 Theme: Data Management and Processing

2 Subject: The Exploitation of Machine Learning Techniques for the Enhancement of Query Optimizer and the Enablement of Predictive Analytics

3 Background

Query optimization has been one of the top challenging areas in database for decades. Both academic and industrial efforts have been made to improve the query optimization. Especially, the conventional commercial database venders (e.g., IBM, Oracle, Microsoft, Teradata, etc.) invested huge amount of resources to improve the query optimizer in their database products. Abundant technologies have been invented by these commercial venders. The performance of query optimizer in current mature database products is a result of continuous efforts for decades from traditional players in this market.

On the other hand, the open source solutions, e.g., PostgreSql, also earn their stand in the market, however, it is still not as mature and well performed as commercial products. Huawei OLAP database is based on such an open source solution which provides the right opportunity to cut in this market. However, similar to some other functionalities that underperform comparing to commercial products, the query optimizer in Huawei OLAP is still in a stage far from mature to perform smart and stable query optimization.

As some of key query optimizer technologies are missing from Huawei OLAP, it is unrealistic to make up this gap and catch up with the mature players in the market in a short life cycle of product. To quickly improve the query optimizer, following the conventional optimizer technologies is one way but may require longer term of efforts. To cut through the path and catch up with the competitors, Huawei OLAP needs to think out-of-box to adopt cutting-edge and disruptive technologies to build its own query optimizer.

Machine learning, as one of the promising approaches in resolving challenges in many data processing areas, including query optimization, has been emerging

recently to attract more interests from the database research community. Some of machine learning technologies have been studied in solving problems of workload management, query execution time prediction, cost model calibration, etc. Such machine learning technologies so far are aiming at the individual problems, where the fundamental framework to exploit the machine learning in database is still missing from the picture.

This collaboration research project is to exploit machine learning techniques and its application in database system, to provide machine learning capability in resolving challenges in query optimization, workload management and optimization, as well as in enabling intelligent predictive analytics for database applications.

Applying the research results from this research would enable Huawei OLAP system to make up the gap of missing technologies, and to be more competitive in both query optimization and intelligent analytics. With the key results from this research, we want to enhance the conventional *BI (business intelligence) capability with new AI technology*. And this research provides the good opportunity to cut through the lane to get ahead of the competitors in the market who are already holding the conventional mature technologies.

The next section lists some problems we are looking for the solutions with machine learning techniques. The list is to be updated with new problems and their solutions with machine learning.

4 Scope

As described in the previous section, this research is to exploit the solutions to provide machine learning capabilities in database system. The first topic is to research and design the overall framework to adopt machine learning technologies in database system, which is currently missing from the research community.

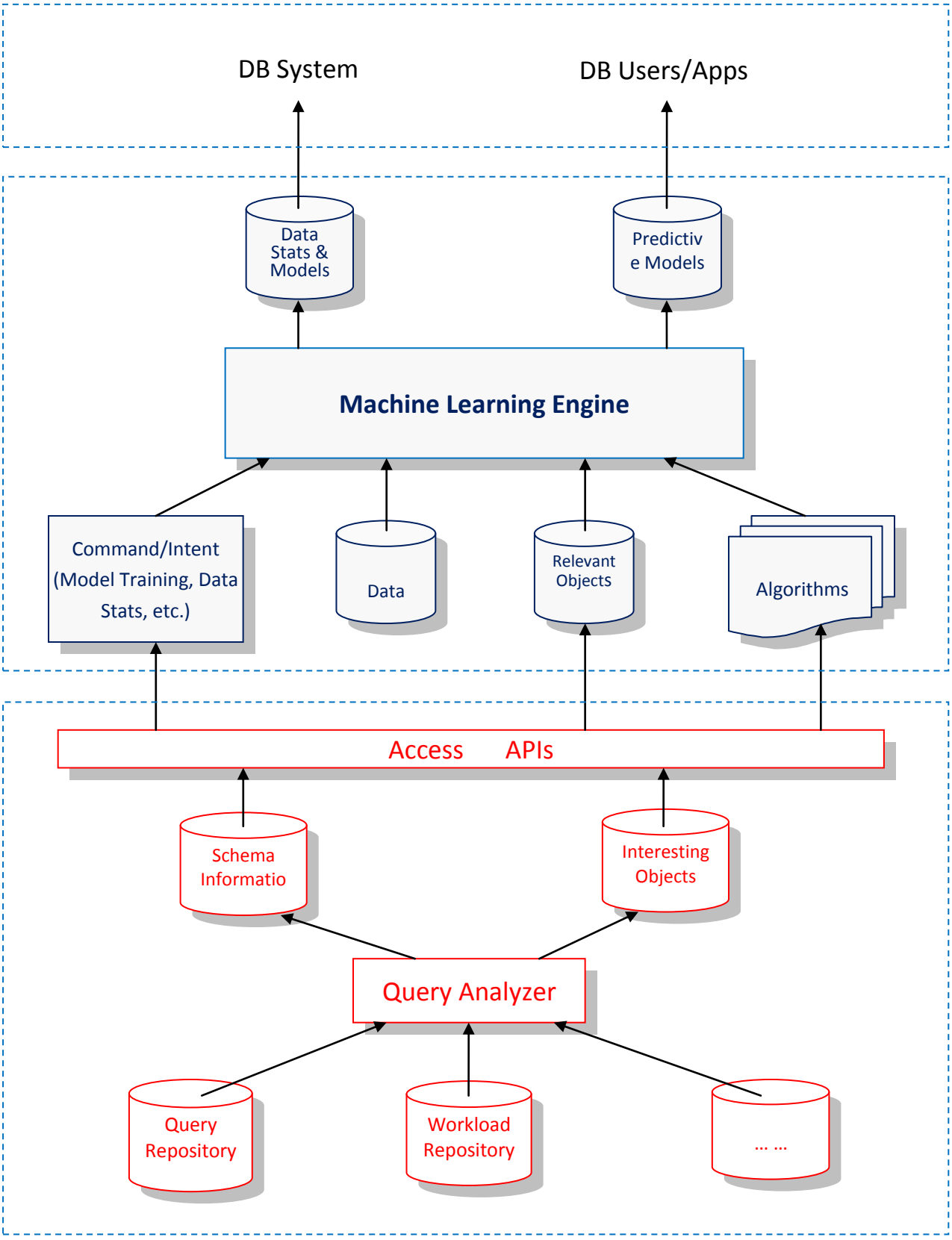
The framework serves as the foundation that provides machine learning capabilities in both database internal and external applications. The research and design of this framework would make the framework efficient, effective, and scalable while smoothly integrate with current database systems.

On top the framework, machine learning technology is exploited in different database application domains, e.g., query optimization, workload management and optimization, as well as intelligent predictive analytics, etc.

Besides the framework and its application in database, some other machine learning and database related problems are explored to further strengthen the competitiveness.

4.1 Framework to adopt machine learning technologies in database system

This is to design an overall efficient, scalable and extendable architecture to build-in machine learning in database. The framework provides machine learning capability for both database kernel internal usage as well as functionalities for external application, as shown next in a design by Huawei. On the top layer, the framework provides two analytics interfaces: IT Analytics to DB System, and Business Analytics to the external DB users and applications. The middle and bottom layers are the components where machine learning capabilities are implemented via direct or extension enablement to DB system.



More specifically, the framework would include the solutions for the following problems:

4.1.1 Machine learning approaches to help query optimizer to better cost and select query execution plans. This is enabled by IT analytics provided by the framework. **(HIRPO2017170507)**

- selectivity estimation of different types of predicates (currently under development by Huawei but joint research and development are welcome)
- cardinality estimation of intermediate results
- cost model improvement, e.g., calibration/tuning (currently under development by Huawei but joint research and development are welcome)
- search and plan selection
- multi-objectives optimization (query elapsed time, resources, throughput, etc.)

4.1.2 Smart operations: using machine learning to adjust capacity, monitor, and predict workload bottlenecks/failures, and to help workload management to achieve better throughput with more efficient resources utilization to meet customers' requirements. This is enabled by IT analytics provided by the above framework. **(HIRPO2017170508)**

- workload resources prediction (currently under development by Huawei but joint research and development are welcome)
- workload throughput prediction
- workload concurrency scheduling
- cloud-based workload management
- workload generation (queries, data, etc.)

4.1.3 Predictive analysis (e.g., trends prediction, fraud detection, risk evaluation, etc.) This is enabled by the Business Analytics by the framework. **(HIRPO2017170509)**

- real-time predictive analysis
- predictive models: e.g., discovering interested objects and patterns
- temporal data based training and prediction
- predictive language and interfaces design

4.1.4 Automated machine learning to provide consumable predictive models and services for both database internal use and external application. This is part of the framework research and design. **(HIRPO2017170509)**

4.2 Accelerated machine learning in database systems (HIRPO2017170510)

MPPDB is a distributed data management platform, which includes relational database system, big data processing, and distributed storage and transaction system, etc. On one hand, machine learning techniques can enable MPPDB's internal IT analytics as well as external intelligent predictive analytics capability. On the other hand, MPPDB's distributed computing system infrastructure may also benefit machine learning technology. In this research, we'd also explore the approach that MPP architecture may help to improve machine learning technology, where some of the potential topics are described next.

Machine learning algorithms themselves may introduce high demand on system resources, e.g., computation, I/O, etc., which could make itself the bottle neck of the database system. To reduce the competition on system resources with database functionalities and to accelerate the machine learning computation, special hardware may be needed:

- GPU/FPGA acceleration
- storage, memory optimization with machine learning in database system distributed machine learning

4.3 Human understandable query interfaces for database system to process new interactive queries. (HIRPO2017170511)

Besides the conventional machine query language (e.g., SQL), using human understandable query interfaces, e.g., natural language, to query the data in the data management systems would provide extra business values as well as its applications for data management systems including database systems. To achieve such a goal, the solutions of the following problems would be needed:

- query input (in natural language)
- query processing framework and implementation approaches including machine learning
- query output & result explanation (in natural language)

4.4 Open problems

We listed the problems with our top priority in the previous sections based on our business requirements. However, other open problems to exploit machine learning technology in database system are also welcome. Upon the

demonstration on business values to Huawei's MPPDB, these open problems will also be considered by Huawei team.

5 Expected Outcome and Deliverables

For each research topic, the following deliverables are checked wherever applies, and benchmark score improvement listed in criteria column is expected however may subject to change based on the individual questions:

3) Software Deliverables

<table>
<tr><th>No.</th><th>Software Component</th><th colspan="2">Acceptance Criteria</th></tr>
<tr><td>1</td><td>Algorithms and pseudo-code of the new solution and techniques</td><td colspan="2">Can be implemented to show the advantage of the new idea.</td></tr>
<tr><td>2</td><td>Source code of the new solution and technique</td><td colspan="2">Can be compiled and executed to show the advantage of the new idea</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">Benchmark test code of the new solution and technique</td><td colspan="2">Can be used to build the environment of testing and reproduce the benchmark result. The benchmark includes, but not limited to, TPC-DS, Join Order Benchmark (JOB), etc. The detailed criteria for some high priority topics can be found as follows:</td></tr>
<tr><td>topic</td><td>criteria</td></tr>
<tr><td>Selectivity/cardinality estimation</td><td>Estimated error can be reduced by at 50%</td></tr>
<tr><td>Cost model and plan search</td><td>Estimated error in term elapsed time can be reduced by 50%</td></tr>
<tr><td></td><td>query plan with machine learning techniques</td><td>overall performance can be improved by 30%</td></tr>
</table>

4) Non-software Deliverables

No.	Content	Quantity
1	Survey of existing related solutions and techniques	1
2	Design document of the new solution and technique	1
3	Benchmark testing report of the new solution and technique	1
4	Idea for patent	1

6 Acceptance Criteria

6.1 Acceptance Criteria：

The success of the project will be proved by the research group working with Huawei's Acceptance Team to evaluate the proposed techniques against the benchmark data specified by Huawei.

Following each evaluation, the Acceptance Team of Huawei will decide on formal acceptance of the relevant Deliverables and will notify the research team accordingly. More specifically,

- The research team will deliver methods, algorithms, design, implementation and experimental results for our techniques, so that the techniques can be evaluated on site at Huawei using real-life data, and lead to an extensive performance report;
- The research team will collaborate with researchers and developers of Huawei for testing and evaluating our techniques at Huawei, and propose solutions to problems encountered at Huawei US R&D;
- Huawei has the priority to own the techniques, when proved successful, and use them in its products, subject to IP negotiation between Huawei and the inventors at the University of Edinburgh.

6.2 Acceptance Environment：

The Project Manager of Huawei will organize the Acceptance Team to review the Reports, and prepare experimental data for the research team. The research team will then set up the testing environment on public environment, e.g., Amazon EC2, Huawei Cloud, etc., to evaluate the techniques against the corresponding benchmark.

6.3 Enablement Workshop:

Both parties would jointly host enablement workshop, preferably face to face, at the beginning of the project, as well as during the project repeat every six months to keep both parties on the same page.

6.3.1 For the kick-off enablement workshop at the beginning of the project:

- Huawei team should come up with a vision document which describes the claim of business value, the main capabilities/functions, the architectural design, the

validation/evaluation plan, and the integration plan.

- The university research team and Huawei team should formally establish the project team with the resource identified and committed.
- The project plan should be created by both parties based on committed resource.

6.3.2 For the repeat enablement workshop during the project:

- Both parties to synch on the same page with the update of the progress
- Functional integration and validation at that stage
- Make changes, if any, to the project plan to adapt to the dynamics of the project.

7 Phased Project Plan

The default length of project development plan for each of the above listed 5 key technologies is 1 year, but feel free to propose longer plan, say 2 year, if needed with defined intermediate milestone targets.

8 Budget

The budget should be provided according to your plan, all the fees should be reasonable and with details. It could be provided according to the table below:

9 Other Information

We listed 5 key technologies in section 4 to explore the research collaboration opportunities, we welcome research collaborator to apply any single one or multiple technologies.

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