SACHER Project. A Cloud Platform and Integrated Services for Cultural Heritage and for Restoration

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ABSTRACT

The SACHER project provides a distributed, open source and federated cloud platform able to support the life-cycle management of various kinds of data concerning tangible Cultural Heritage. The paper describes the SACHER platform and, in particular, among the various integrated service prototypes, the most important ones to support restoration processes and cultural asset management: (i) 3D Life Cycle Management for Cultural Heritage (SACHER 3D CH), based on 3D digital models of architecture and dedicated to the management of Cultural Heritage and to the storage of the numerous data generated by the team of professionals involved in the restoration process; (ii) Multidimensional Search Engine for Cultural Heritage (SACHER MuSE CH), an advanced multi-level search system designed to manage Heritage data from heterogeneous sources.

CCS CONCEPTS

• **Information systems → Relational database model**; **Cloud based storage**; **Information lifecycle management**; **Extraction, transformation and loading**; **Online analytical processing engines**; • **Computer systems organization → Cloud computing**;

KEYWORDS

Cultural Heritage, Integrated cloud platform, Cultural Heritage data life-cycle management, 3D Digital Models, Restoration, NoSQL database, Multidimensional data analysis, ETL process

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1 INTRODUCTION

The promotion of the tangible Cultural Heritage (CH) represents a strategical asset for the development, innovation and renewal of the cultural and tourism circuits of art cities. Many efforts have been devoted to develop services that enable tourists to take advantage and appreciate the Cultural Heritage of cities, but only few solutions are targeted at supporting professionals in their working activities, such as restorers. In particular, it is still lacking an advanced ICT platform able to manage CH data life-cycle taking into account restoration and preservation activities necessary to ensure its fruition to the public.

The Smart Architecture for Cultural Heritage in Emilia Romagna (SACHER) project intends to fill this gap by creating an innovative and open source ICT platform based on Cloud Computing technologies, able to integrate preexisting ICT platform in public and private entities, facilitating the storage and usage of CH data both for specialized users and for the public.

The SACHER platform is able to provide unique identification tools and 3D modeling of Cultural Heritage as well as application services for leveraging access, analysis and advanced data presentation. In particular, in the design of CH data presentation,

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visualization and input services SACHER adopts a participative design approach to foster cultural service creation through the involvement of content users (tourists, citizens) and cultural experts (scholars, researchers, public institutions). Thanks to its technological support, SACHER organizes and generates a permanent ecosystem of actors producing new value chains in the collaborative fruition of services for cultural assets.

The paper is organized as follows: Section 2 sketches relevant related works; Section 3 presents the SACHER project, focusing on the Cloud infrastructure deployment; Sections 4 and 5 describe the two developed service prototypes SACHER 3D CH and SACHER MuSE CH; Section 6 presents testing results on the prototypes, while Section 7 concludes the paper with some final remarks and future work.

2 RELATED WORKS

In recent years, digital innovation is increasingly influencing the Cultural Heritage domain. While great effort has been devoted to design innovative digital tools for disseminating CH among tourists and citizens, such as new generation applications (virtual museums, digital libraries, multimedia itineraries, visual presentations, etc.), advanced professional instruments designed for operators working for the enhancement and protection of cultural assets are still lacking. Some applications and informative systems have been developed, but they address only particular needs, i.e. quick annotation on 3D models [12], semantic annotations for enriching various kinds of information [10], BIM solutions and ontology-based web platforms for managing extremely large amounts of information [8], advanced tools for diagnostics (CO.B.RA Project: http://cobra.enea.it/). These solutions are not always flexible outside their scope and often not addressed to non-experts users. An overview on the state of the art of different existing web-platforms for CH data management is described in [3]. Other available solutions provide professionals with more user-friendly tools, i.e. the SICaR Information System [5] that is a web-platform used for geo-referenced documentation for public restoration sites. However, it can currently only support bidimensional vector drawings and not 3D models, which restoration operators strongly require.

A very recent trend that is emerging in other ongoing projects is developing platforms based on cloud technologies, such as Forma Romae Information System (http://www.ponmetro.it/), that uses open geodata for the management of historical, archaeological and architectural information, but it will take a few years yet to be operational.

Differently from available solutions, SACHER is a more general purpose infrastructure for supporting restoration and maintenance activities that integrates a variety of user-friendly services with advanced facilities, such as 3D model annotation for professionals, and provides a cloud computing-based platform for enhancing service scalability and deployment.

3 THE SACHER PROJECT

SACHER is a project for Cultural Heritage financed by Emilia-Romagna Region within the European Regional Development Fund (POR FESR 2014-2020).

The project contributes to the promotion and protection of Cultural Heritage, by providing cultural institutions, experts in conservation-restoration and the entire community with an innovative ICT platform facilitating the whole CH data life-cycle management. Using Cloud Computing based technologies and an Active Digital Identity paradigm, SACHER provides users with a fully distributed and open source platform which can integrate various hardware and software infrastructure of both public or private operators, collecting data related to the vast national Heritage.

As a key feature, SACHER provides, on top of the cloud platform, customizable service applications for data access, analysis and display targeted at both CH experts or tourists. The paper focuses on two main services, the SACHER 3D CH and the SACHER MuSE CH, aimed at facilitating restorers in their activities. The project fosters the consolidation of new models of cultural business through the integration of public and private actors working within social entrepreneurship and ICTs.

The validation of the SACHER platform and services has been carried out in collaboration with the Municipality of Bologna on the monuments of the historic city center, releasing a trial version of the final product that can be quickly transferred to the market and available in various contexts of art cities (www.sacherproject.com).

3.1 SACHER Cloud computing platform

One of the primary objectives of the SACHER project is to provide a cloud platform to host and support all applications dealing with CH data and their life-cycle management. In recent years, the cloud computing paradigm has been widely adopted because it allows to take advantage of all the benefits of virtualization. Among the advantages, the adoption of cloud technologies provides services and resources dynamically and continuously and offers a scalable and easily manageable infrastructure that provides IT resources on demand significantly reducing the time and costs of software deployment and time-to-market.

To host the applications and resources of the SACHER project, an ad hoc infrastructure based on the private cloud model has been set up. This choice allows us to have full control over architectural choices, for example the choice of cloud software and those related to security, maintenance and deployment of the infrastructure. In the public cloud model, in fact, all the resources and applications are controlled by the service provider while in the private cloud they are managed and used exclusively at the organization level with an increase in the level of security and privacy.

The cloud infrastructure created is also easily federable with other cloud platforms belonging to both public and private entities. This allows to interoperate in a simple and flexible way sharing its resources and services and taking advantage of external ones.

3.1.1 The Openstack cloud platform. The cloud platform used for the SACHER project is the IaaS Openstack project. It is a mature open-source product created in 2010 by NASA and Rackspace and released under the Apache license which currently counts the collaboration of over 500 companies including: IBM, Intel, Oracle, Yahoo!. The version used is the latest available on the date of installation (May 2017), i.e. Ocata. The deployment tool is devstack, which, although not properly addressed to a production deployment, allows us to develop and extend Openstack's services.

The architecture of Openstack consists of a set of components called services. Each service has a specific role. For example, the Keystone service manages authentication and authorization for the various OpenStack components; the Nova service manages the underlying hardware resources by interacting with both VMM (Virtual Machine Monitor or Hypervisor) and with bare machines; Neutron addresses the management of network functions (e.g. routers) between Openstack, Virtual Machine and external services; Swift is an object storage system that manages objects and files ensuring replication and integrity of data; Glance provides a catalog for storing and managing virtual images.

The adopted deployment model of Openstack services in SACHER consists of two types of roles: the controller node and the compute node. The node controller is the host where most of the shared services are located while the compute node is the host where the virtual machines (VM) reside. Using the Openstack model allows horizontal scalability achieved by simply adding new compute nodes. In our case, the node controller does not only maintain the common services but is also used to host the VMs.

3.1.2 Openstack distributed network architecture and software layers. The Openstack nodes communicate over local LAN networks; in particular to keep the traffic separated we have chosen to use two distinct networks, one dedicated to the communication between the services located on different nodes (management_net) and one dedicated to the communication between virtual machines (data_net). For the SACHER project, in particular, the Openstack network architecture is distributed between two remote locations (Bologna and Cesena) for which it was necessary to connect two local ethernet networks (with private addresses) using two VXLAN tunnels and two hosts acting as NATs (Network Address Translation).

The federated and distributed cloud platform was further extended by the partner company Imola Informatica, which added a node (compute) to the data center of the EXE company of Castel San Pietro (BO). The new node enables the emulation of distributed deployment scenarios on a larger scale and the implementation of stress test performance of distributed file systems for Infrastructure as a Service (IaaS) environments and of environments and tools for simplified container management and automatic elastic scalability.

Figure 1 shows the structure of the cloud infrastructure from a software and hardware layer point of view. At a lower level we find the physical hardware typically made up of multiple servers distributed in different data centers, going up we find the first software layer that is the OS (Operative system) of the servers on which the Openstack cloud platform is installed (orange). Above the cloud platform we have the VMs with their respective OS (purple) on which the applications are installed. To facilitate the deployment of applications it may be useful to exploit an OS virtualization system better known as containerization as Docker (blue). Figure 1 also underlines the presence of another important cloud service, namely the Object Storage Swift, for saving large multimedia files such as, for example, those nexus (.nxs) used by the SACHER 3D CH and SACHER MuSE CH services for referencing and for storing the 3D models.

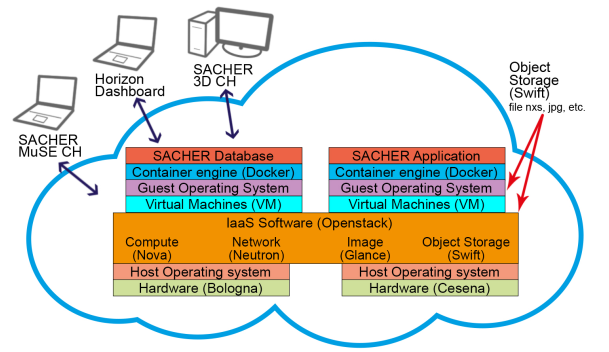

Figure 1: SACHER services and Cloud infrastructure layers.

3.2 Developed service prototypes

The SACHER cloud infrastructure hosts a series of services related to CH, providing restoration operators with customized tools, and the community with user-friendly applications aimed at improving citizen and tourist knowledge of Cultural Heritage. From the application services point of view, the main SACHER services integrated on top of the cloud infrastructure are:

(1) SACHER 3D CH (3D Life Cycle Management for Cultural Heritage) manages the life-cycle of CH data (e.g. upload, consultation, 3D model);
(2) SACHER MuSE CH (Multidimensional Search Engine for Cultural Heritage) processes CH data using NoSQL Database and an engine for multidimensional data analysis.

Besides the SACHER applications, system administrator can manage the entire cloud infrastructure (e.g. virtual machine creation, snapshot) using the Openstack service called Horizon dashboard.

4 3D LIFE CYCLE MANAGEMENT FOR CULTURAL HERITAGE

The current debate among experts in the restoration sector focuses on many aspects, including the issue of managing the huge amount of non-homogeneous data in order to devise an effective system for ensuring a proper storage, access and sharing of documentation, going beyond methods traditionally used. According to up-to-date scientific literature, the actual trend in data curation and dissemination is based on a varied range of solutions [1, 2, 5, 7, 8, 10, 12].

Against this background and after studying the state of the art of the existing web-platforms for CH data management [3], the multidisciplinary working team with the help of skilled restorers collaborating to the project has modeled a complete and customized service on the real needs of on-site workers, providing suitable solutions to the critical issues (e.g. simple integration of fragmented data by various archives, interoperability with existing platforms, storage of large files, reliable visualization of 3D reality-based models, quick connection of information to the semantically divided digital surface, user-friendly tools for specific data-entry and documentation query activities, usable end-user interface for non-experts, flexibility of the service to adapt to various architectural categories).

4.1 The SACHER 3D CH Service

The SACHER 3D CH service is intended to provide users with an efficient and advanced informative system, whose purpose is the management of Cultural Heritage, especially during all the phases of the restoration process.

The service addresses in particular professionals in the field of Cultural Heritage restoration, as well as public institutions in charge of its protection, preservation and enhancement. The service in fact allows on-line management tools for the collection, cataloging and conservation of the numerous data and documents generated by all experts involved in the work during all phases, namely for documentary and operational purposes prior to the restoration project, during the restoration site interventions and related to the subsequent maintenance activities.

Moreover each kind of device, even with limited performance, can enter the service via the Internet with no need to install any software, making the service suitable for on-the-spot work and support. Access is possible in multi-user mode, to give the opportunity to all operators to work simultaneously and ensuring real-time sharing of contents and immediate feedback between professionals of the work and authority responsible for constant monitoring the progress of restoration site.

4.2 Main features

4.2.1 CH location on map and identification. Protected heritage managed through the service is displayed with locators pointing out the position of the building on Google Maps. Search is helped by filters on name, address and building type. The selection of a marker opens a pop-up with noteworthy historical information, also accessible to general public, as well as the exploration of three-dimensional content. Each cultural asset is identified by a collection of various mandatory fields for accurate description, compatible with vocabulary choices by the Italian national institute for documentation, ensures interoperability with other systems and allows gathering available information in existing open databases.

4.2.2 3D models and graph definition. At the core of the system is the three-dimensional digital model with semantic structure of the building, both for data association and information retrieval. Reality-based 3D models with high-detail textures created by means of terrestrial laser scanner or photogrammetry in fact provide the user with useful information on shape and dimensions and chromatic aspect. Upload of the reference model is intuitive, such as the possibility to customize the semantic structure representing the partition of the building in sub-levels and elements according to the required granularity (Figure 2). Different tools support the user, both for optimized navigation in the virtual environment and for the interaction with the 3D model.

4.2.3 Data-entry and information query. Historical, cultural and technical data are efficiently organized and entered into the service with operations, namely sheets linked to 3D elements referring to specific cataloging categories (activities, stages of work, etc.) and enclosing different kinds of documents (images in various formats, vector drawings, alphanumeric texts, audio/video recording, etc.). Further data can be georeferenced to a specific point located on the model through 3D reference spots (Figure 3). An intuitive and easy-to-use interface was designed especially to quickly retrieve entered information, both by filtering the operation list or selecting a specific 3D item or spot.

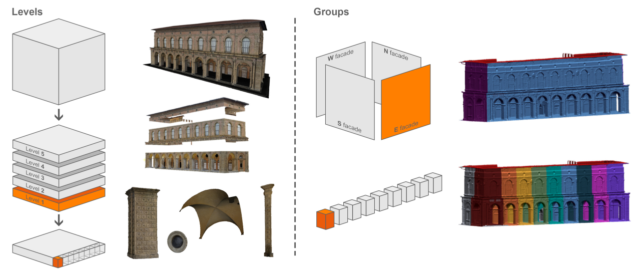

Figure 2: Partitions of the 3D model of the Palazzo del Podestà in Bologna showing levels and groups.

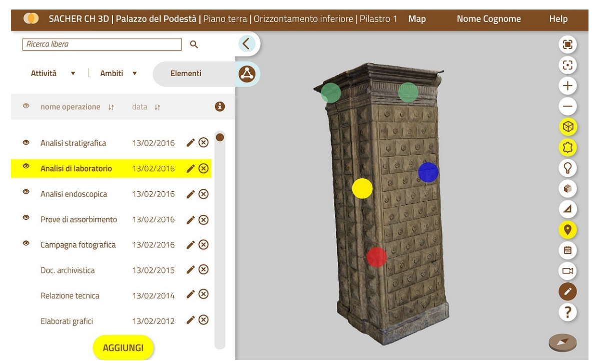

Figure 3: Operations connected to the digital model of architectural elements and georeferenced by 3D colored spots.

4.3 Architectural solutions

SACHER 3D CH, as web service, allows the management of CH, starting from the interactive visualization of the 3D models on web browser up to the management of the restoration processes. The SACHER 3D CH web application has been developed using a set of frameworks, configured to provide the best combination in terms of efficiency and speed. All the developed code is publicly available and it can be found at https://github.com/SACHER-project/SACHER.

The service is mainly based on Django https://www.djangoproject.com/ framework, a high-level library written in Python. Django lets to define various models, which are fundamental to manage the multi-user and multi-group interaction or to store all the CH detailed information. All these data are stored in a MySQL relational database management system (RDBMS), hosted by a virtual machine (VM) that it is different from the one which hosts the SACHER 3D CH web service.

Since 3D models of CH could be very large, a service that offers scalability, replication, and integrity of data is required. Therefore, the Object Storage (Swift) is chosen to retrieve the 3D models. Swift directly communicates with Django, providing the requested resource and avoiding to involve the relational database.

In order to interactively display 3D objects, SACHER 3D CH is enhanced with 3D Heritage Online Presenter (3DHOP) [11], an open-source library for the creation of interactive Web presentations of high-resolution 3D models. To exploit all the potentialities of this library, the multiresolution approach is employed. Therefore, we split the geometry into smaller blocks, allowing the rendering and loading of only the parts of the model that are strictly necessary for generating the current view. With this approach, the model is immediately available to user, even though with low resolution, and it is constantly updated with new progressively loaded data.

5 MULTIDIMENSIONAL SEARCH ENGINE FOR CULTURAL HERITAGE

SACHER Multidimensional Search Engine for Cultural Heritage service (SACHER MuSE CH) is an advanced multi-dimensional search system for heritage data coming from heterogeneous sources. Aiming at providing a unified view for heterogeneous CH data, we have designed a set of Extract, Transform and Load (ETL) workflows that extract data from various CH providers (for example, IBC and WebGIS in Italy) in various formats (MySQL, flat files and RDFs). These data are thereafter feeded into a central data lake repository. The crucial feature of the MuSE service is that it offers an umbrella that covers data in all possible formats, thus providing a baseline for all kind of analytics for all levels of users, including transactional, executive and administrative users. Most significantly is the MuSE ability to do multidimensional analytics that enables decision makers who are working in the CH sector to make strategic decisions regarding CH restoration projects, including decisions regarding human power and funding. All of this is possible through the utilization of a NoSQL (specifically MongoDB [4]) database service.

5.1 SACHER Data Lake design

5.1.1 Overview. Data Lake (DL) is a centralized repository of raw data into which many data-producing streams flow and from which downstream facilities may draw [6]. The main driving factor for using Data Lakes in SACHER is data variety and the possibility to identify business strategies. As shown in Figure 4 our data lake consists of three zones: *raw zone*, containing data in its original format; *refined zone*, containing transformed datasets created from raw data through ETL, including new data models (star schema model suitable for multidimensional Online Analytical Processing (OLAP) and cube analytics), data quality enforcement; *trusted zone*, containing master datasets used in combination with refined data to answer specific end-user queries.

5.1.2 SACHER Multidimensional Data Modeling. We have decided to enrich the *refined zone* with multidimensional models that are utilized for strategic decision making. Multidimensional analysis (MDA) is a data analysis process that groups data into two categories: data dimensions and measurements. Examples of multidimensional queries include "finding all restoration operations grouped by location, time and activity type".

A data warehouse is based on a multidimensional data model which views data in the form of a data cube [9], which in its turn allows data to be modeled and viewed in multiple dimensions (Figure 5). For instance, dimension tables include information such as

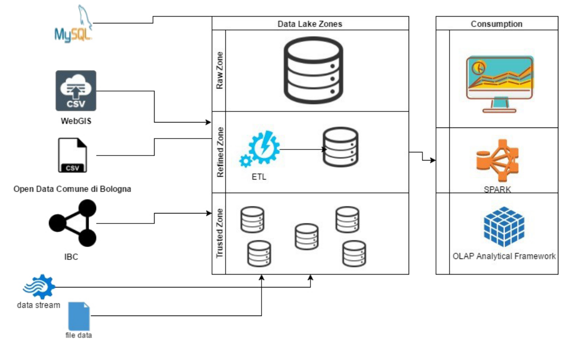

Figure 4: SACHER Data Lake Architecture.

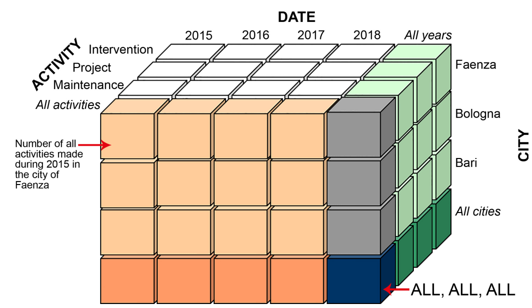

Figure 5: Sample data cube.

location (city, district), or time (day, week, month, quarter, year). Fact table contains measures (such as total_restored) and keys of each of the related dimension tables.

5.1.3 Deployment. SACHER MuSE is a data management service that spans several stages throughout SACHER platform, thus offering data quality guarantee via ETL (Extract, Transform and Load) including the following: reformatting several heterogeneous sources to comply with a unified MuSE format, cleaning source data, discover and resolve outliers. Also, fuzzy join is exploited for joining autonomous CH restoration locations on non-equal attributes such as "name" and "address". We have designed a distributed cloud-based repository that offers a baseline for every type of analytics and querying.

Multidimensional model for business insights. We have designed a unified logical schema that is intended to digest related CH data from multiple heterogeneous sources. Sources include: (i) SACHER 3D CH; (ii) IBC Istituto per i Beni Artistici, Culturali e Naturali della Regione Emilia-Romagna; (iii) WebGIS E-R Patrimonio architettonico tutelato dell'Emilia-Romagna.

Those sources have different data formats for same datasets. Our logical schema constitutes a multidimensional model that is composed of fact and dimension tables, a star-alike schema where a centralized fact table is surrounded by multiple dimensional tables, thus offering a high-level architecture for advanced business insights. Example multidimensional analytics include: (i) aggregate restoration operations by "municipality" by "year" by "activity type"; (ii) aggregate restoration operations by "activity" by "district" by "month". Those assist business managers in discovering deep insights that facilitate decision making process, assisting for example in answering questions like: (i) which restoration project is consuming more budget; (ii) which project has been prolonged and how this link to the time that it has been on work; (iii) how much should we fund subsequent similar projects and when to start the restoration. In SACHER however, we have decided to use NoSQL DB MongoDB because it allows schema-less models design and allows and offers horizontal scalability once data size goes beyond permitted capacity.

As a final consideration, we can also perform a set of simplified OLAP Operations in SACHER throughout our multidimensional design including roll up (drill-up), where we summarize data by climbing up hierarchy or reducing dimension. For example, we can roll up to the level of regions (upper level of cities), thus showing total annual restorations for "intervention" activities in each region aggregated by year. We also perform reverse of roll-up (called drill down) from higher level summary to lower level with the same context.

6 EVALUATION AND FEEDBACK

At the final stage of the project, a testing phase of the two service prototypes has been carried out before the SACHER platform release.

For SACHER 3D CH, an online questionnaire has been specifically prepared and given to a sample of experts among restorers, professionals of the field of CH, operators of public institutions, etc. Questions aimed at obtaining feedback on the usability and usefulness of the innovative tools designed for SACHER services, not present in other similar applications. In general, end users appreciated the user-friendly interface of the service providing positive feedback on the advanced features designed for interaction with the 3D digital model and on data link tools, and on the efficiency of the prototype improved thanks to the adoption of cloud computing technologies.

The SACHER MuSE service was also tested within the context of the CH data generated by the SACHER 3D CH service. In particular, SACHER 3D CH service has been put forward to input every single restoration operation that is being conducted in every CH restoration location in Emilia-Romagna Region in Italy. SACHER 3D CH Service is transactional, thus every restoration operation is saved in a table that is linked to some other tables in a relational model. For example, some of the tables include "operations", "activity" and "category". Referential integrity is enforced using primary and foreign keys. Discovering business analytical insights from such a transactional schema is yet challenging. For example, a multidimensional query may seek an answer to the following: aggregate restorations by district, by year and category. This normally requires complex multi-way join queries that normally launch a cartesian product among participating tables, thus heavily taxing the transactional system. The SACHER MuSE CH service addresses also the issue of data quality, enabling to clean data and to discard duplicate values.

7 CONCLUSIONS

The SACHER platform provides an efficient system for stable documentation over time through the use of 3D models aimed at improving cultural experiences. CH data management, acquisition and storage procedures and the SACHER cloud infrastructure are made available to cultural sector operators, providing new advanced services and operating methods characterized by minimum barrier to technology access and with reduced implementation and management costs. The use of European standards such as FIWARE, significantly extended by the addition of new API standard at the IaaS/PaaS level for capturing, storing and storing CH data, makes the SACHER platform flexible and usable in other contexts.

The service for CH data management, tested by restorers on monumental buildings of Bologna city center, had a positive feedback from users and will be further implemented.

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