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教員と制作チームの支援のための MOOC データマネジメントポータルの開発

Development of MOOC Data Management Portal for Instructors and Production Team

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Abstract

Massive Open Online Course (MOOC) instructors and production teams have a common challenge in monitoring multiple MOOCs, course re-runs, and the associated MOOC-generated data. We developed a MOOC Management Portal to monitor, administer, and curate a range of MOOC metrics because there was no comprehensive solution available. The developed system is evaluated using real MOOC data, and it is capable of securely, efficiently, and reliably handling such data. As a result, the system enables the instructors to monitor their repeating courses for course improvements, and the production teams can provide useful feedback to the instructors, being able to create reports for multiple courses.

Keywords: Learning Analytics, Analytics Dashboards, edX, MOOC, Information Visualization, Decision Support Systems, Big Data

1. Introduction

Online education has changed tremendously in a favorable manner during the last decade and is expanding in many dimensions. The COVID-19 pandemic has pushed online education to new heights and put it to the test in ways it has never been tested before.

In the fast-growing online education space, MOOCs have, as the name suggests, created greater room for participation and the MOOC's vastness presents a substantial barrier to the management of data and the application of analytics. With the intricacy of MOOCs and the rapid development of web technologies, a plethora of data points are able to be collected. Different MOOC platforms have their own distinct administration and data analysis systems, but many MOOC-delivering institutes want a system with more flexible MOOC management and in-depth bespoke data analysis. MOOC-related research has made a significant contribution to the gradual maturity of the MOOC ecosystem, and individuals, as well as individual institutes, should be driven to take MOOC research to a deeper and broader range of causal factors, beyond merely ubiquitous analytics [1].

Kyoto University currently offers MOOC courses on edX [1], with sixteen (16) unique course offerings and seventy-six (76) re-offerings since its inaugural MOOC course, enrolling over two hundred and eighty thousand (280,000) students. Kyoto University also offers MOOC courses on Japan Massive Open Online Education Promotion Council (JMOOC) and the University's self-managed MOOC platform (KoALA[2]). As Kyoto University offers a considerable number of MOOC courses, which are developed and maintained by a small centralized team, the assistance of a robust centralized MOOC administration and deep analytics system could alleviate the workload and improve MOOCs and MOOC production. The absence of such a system in the MOOC arena has created an opportunity for such development to take shape.

2. Background and Considerations

Around the time that the higher education industry was focusing on MOOCs in 2012-2013, Kyoto University became interested in MOOCs and developed its first MOOC course in 2013.

Kyoto University, being one of the leading MOOC providers with a relatively small MOOC production team [2], encourages us to find and optimize our MOOC production, analysis, and reporting procedures and mechanisms. We developed the KyotoUx[3,4] Management Portal (KMP) to support MOOC production and management. We also developed other course data visualization tools [3].

2.1. Track and manage MOOC activities

Kyoto University operates a central MOOC production team for all its courses and the key feature we were looking for is a place where the MOOC production team, MOOC instructors, and their teaching assistants (TAs), can view the status and activities of their MOOCs. edX offers their own version of insights for each course, as well as a small selection of overall cumulative insights for their partners. Two main issues stem from using their system, including the fact that for our MOOC team to access edX insights[5] we

[1] https://edx.org
[2] https://koala.highedu.kyoto-u.ac.jp
[3] Universities partnering with edX will brand their courses "[university name]X."
[4] https://www.edx.org/school/kyotoux
[5] https://insights.edx.org

must enroll our internal MOOC team members in all courses, and we wanted improved depth analysis for some key metrics.

2.2. Automate data pipeline

Kyoto University offers its MOOCs mainly on edX which creates a research data package including learner daily event files, weekly database files, and learner email opt-in reports [4] for each edX partner. This data package is encrypted with Gnu Privacy Guard (GPG, industry-standard encryption protocol) to ensure secure data transmission between edX and its partners. Then each edX partner's Data Czars[6] retrieves the data from the shared Amazon Simple Storage Service (Amazon S3). More details are available [5] in the well-explained edX official documentation.

Usually, without any automation, we can download data from the edX Amazon S3 bucket, decrypt files and analyze said data using various data analysis tools including custom Python scripts. As this manual process needs a considerable amount of time, effort, and dedication, we desired a simpler system for automating the data pipeline that could handle each data package in a hassle-free and secure manner while using fewer resources while increasing efficiency and reliability.

One of the primary concerns in data analysis is data security and privacy [6]. Some important elements of data security are data encryption, data transfer, data storing, allowing secure access by authorized personnel, and a proper data disposal procedure [7]. Automating the data pipeline can increase data security by avoiding having multiple copies on multiple devices, and anonymizing and filtering data before it reaches endpoints.

2.3. Analyzing and report generation

As mentioned above, edX provides universal insights for each partner institute, and although it includes most of the valuable key data points it still falls short of our unique interests, such as access rate, grade comparison, most visited and repeatedly visited course modules, and units, average grades for each module within the course, and a comparison of the course performance metrics across its reruns. Visualizing data is a critical step in understanding the underlying patterns and properties of the data. Multiple studies show that visualizing data helps human cognition and improves decision quality and decision-making speed [8].

In addition to visualizing data in a meaningful way, we are interested in readily available reports for the MOOC assessment team, production team, course instructors, and other relevant parties. Usually, when a course is finished our MOOC assessment team creates an extensive report for the course run including various data points before sharing it with the course instructor and other relevant parties [9]. Making course reports required several assessment team members, and if multiple courses are finished at the same time it takes a great deal of time and work.

2.4. Notifications

At the time of writing, the majority of MOOC courses at Kyoto University are offered in self-paced mode with learning occurring throughout the entire academic year. Several of the MOOCs are scheduled to start and end on the same date. As such, automatically generating email notifications would make it easier for early preparation and reduce the risk of missing important deadlines.

3. Related Work

Many studies have shown how dashboards are important pillars of Decision Support Systems (DSS) and have the advantage of providing all stakeholders with a consistent perspective and the same version of data [10]. The history of digital dashboards goes back to the 1970s when they started being used in the automotive industry [11-13]. Digital analytics dashboards as we know them today did not appear until the late 1990s. The growth of web technologies in the late 1990s opened new horizons to online analytics tools and dashboards [14, 15].

When MOOCs attracted global attention in 2011-2012 this is when most of the current MOOC platform providers emerged including edX [16] and over the past several years the global MOOC ecosystem has grown tremendously [17]. It opens up new avenues for MOOC-related research including learner data analysis and analytics dashboards. All the MOOC platform providers have some form of an analytic dashboard and as Kyoto University uses edX and Open edX to offer its MOOCs we will mainly focus on edX research data and related analytics. As edX releases its research data package to its partner institutions most of them have their own in-house solution to analyze and utilize the data. Some of them are open source and freely available to anybody [18].

Each individual institution and MOOC have different pedagogical approaches to the MOOC world [19]. So, the MOOC management and analytics approaches are also unique to each institution and have advocated different interactions and designs. With the increased usage of MOOC, the literature reveals [20-23] that several very interesting MOOC management and analytic dashboards have been developed.

Various MOOC data analytics tools have been developed for internal use over the years, and in 2018 we created a centralized minimum viable product (MVP) called KyotoUx Management Portal (KMP) that included some of the required features, such as an automated data pipeline, courses page, individual course run page, report generation, and notifications [24]. KMP (v1) had its own limitations when it came to performance, especially data processing, the user interface (UI), and user experience (UX). KMP (v1) uses Python with the foundational data processing library Pandas, one of the most powerful data analysis toolkits available [25].

Processed data is then stored in MySQL relational database. MySQL-like Relational Database Management Systems (RDBMS) are well known for their performance

[6] https://edx.readthedocs.io/projects/devdata/en/latest/data_czars/

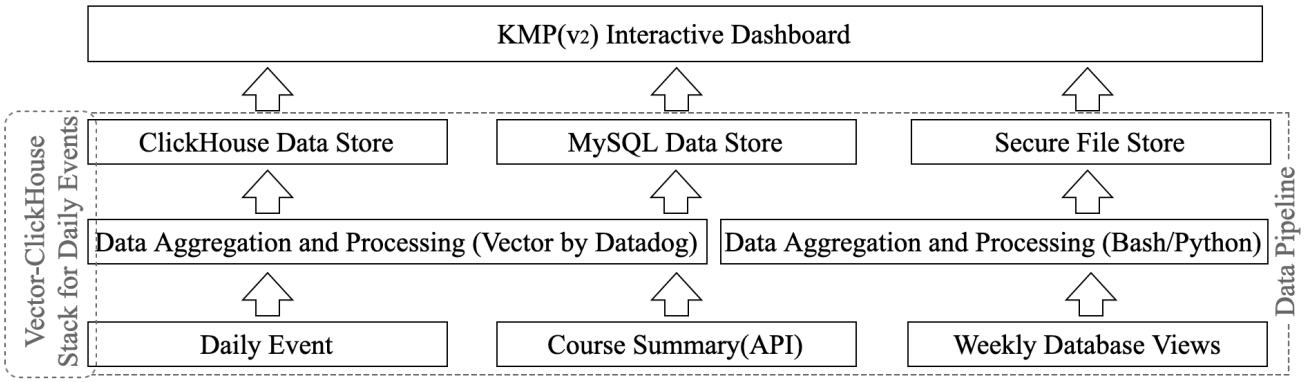

Figure 1. Data pipeline and dashboard

limitations for deeply nested data structures with multiple join operations [26]. When authenticated users access KMP (v1) it pulls data from the MySQL database for each request and displays it in various frontend charts, and tables that are handled by JavaScript (JS). This increases response time significantly and the MySQL database server handles the same queries over and over. As we get the research data package weekly it's not necessary to read the same data repeatedly from the MySQL database.

4. System Functionality

With the requirements in section three (3), we have developed a simple yet powerful web-based MOOC tracking and analytics platform.

4.1. Data pipeline (Analyzing and processing)

Our proposed KMP (v2) uses two different data sets; (1) Course summary data from edX API, and (2) edX research data package. edX offers Application Programming Interface (API) access on a request basis to partner institutes. To obtain API access credentials edX partners must request API access through the API access form[7] using an institutional email address. edX provides a variety of important API endpoints, and for KMP (v2) we primarily use two API endpoints to automate the fetching of course and course run summaries.

The edX research data package for each partner institute contains two main components, namely learner event data and database data. Learner event data is generated and released on a daily basis and contains a log of course events. Database data is generated and released on a weekly basis and contains different views exported as Structured Query Language (SQL), Comma-Separated Values (CSV), and Mongo. Our proposed system automatically pulls event data daily and database data sets weekly.

We use Bash shell scripts with Cron which are scheduled to run at the specified time to execute Python scripts to pull and process course summaries and the weekly edX research data package. That process handles cleaning, filtering, data anonymizing, storing required relational data in a MySQL database, organizing data into required JSON objects, and putting insecure file storage for easy and low latency quick access for the frontend dashboard.

We separately process learner event data (Figure 1). edX captures learner event data in many possible ways[8] and contains gigabytes of learner events that are pulled daily to the data aggregation store. To process this large data set we propose two open-source tools, Vector by Datadog[9] for processing and aggregating data and ClickHouse[10] to store processed data.

Vector is an open-source lightweight high-performance tool that can build an end-to-end (agent & aggregator) observable data pipeline that can collect, transform, and route logs. When KMP (v2) pulls data from edX, Vector automatically detects the most recent file and processes the data before routing it to the ClickHouse data store. Vector has three main configurations, (1) Data source, (2) Data transform, and (3) Sinks (push to another location, in this case to ClickHouse). ClickHouse is a free and open-source powerful column-oriented yet tremendously fast database management system that can handle a massive volume of data [27, 28].

4.2. Authentication

Proposed KMP (v2) is intended to be used internally at Kyoto University and is only available to authorized personnel. Anybody who comes to KMP (v2) first lands on the login page and should authenticate using their credentials.

4.3. Main page

The main page provides an overview of information about KyotoUx MOOCs. After authenticating, users are automatically redirected to the main page, which offers a range of data points and metrics. It displays total course

[7] http://courses.edx.org/api-admin/
[8] https://edx.readthedocs.io/projects/devdata/en/stable/internal_data_formats/event_list.html
[9] https://vector.dev
[10] https://clickhouse.com

runs, total enrollments, total individual learners, and total learners with a passing grade beginning at the top of the page. The following sections show all engagements, enrollments, unique learners, and video activities for the previous 7 and 30 days, respectively. Following that, there is a chart of course runs versus year, a chart of enrollments versus year, a chart of weekly enrollment change, and a summary chart of presently running courses (enrollments, verified learners, and passing learners). The following section includes a count of archived courses, presently open courses, instructor-paced courses, self-paced courses, and confirmed enrollments. Further down, there is a map of learner location/geography, an age distribution chart, a chart of learners' education level, and a table of enrollment summary by academic year, as well as a list of ongoing courses with the start date and end date.

In general, we manage three types of access roles and permissions: administrator, KyotoUx staff, and course instructor. Administrators and KyotoUx staff can see almost everything, whereas instructors can only see their course-related data.

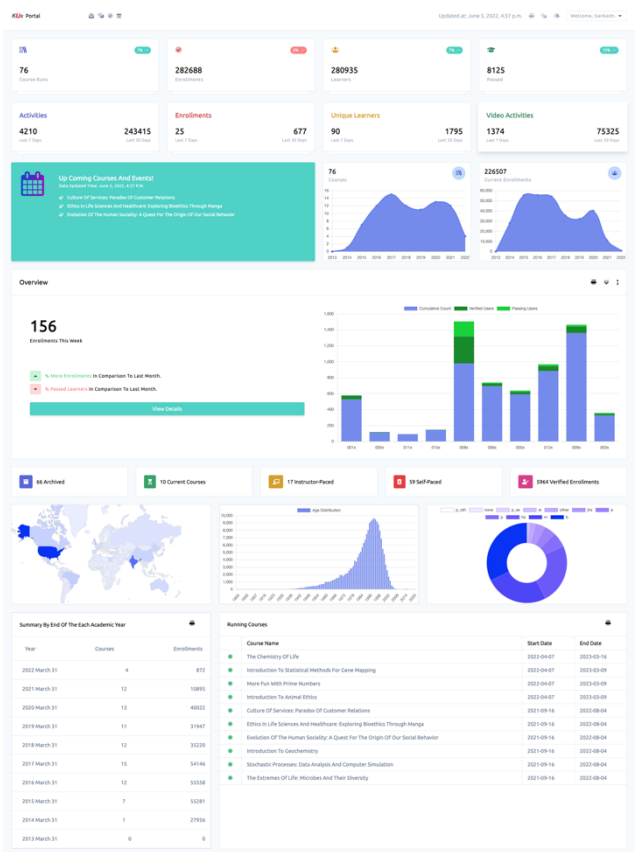

Figure 2. Main page

4.4. *Courses*

As discussed in the introduction, MOOC courses generally run multiple times over the years. On the courses page, we can see a quick summary of each course throughout its course run history. This includes total enrolled learners, passed learners, verified learners, and enrollments vs grade chart for each course run.

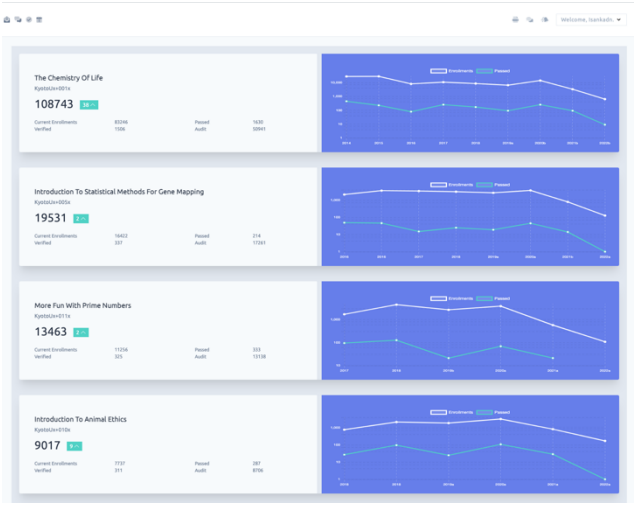

Figure 3. Courses page

4.5. *Course runs*

The course runs page starts with an interactive chart that comparatively displays course enrollments, verified learners, passing learners, and verified passing learners that can be enabled or disabled if needed for further contrast of data. The next table includes run details for all courses, sorted by the course end date. If the course is still running, the date displays on a green background. All course names are clickable and linked to individual course pages.

Figure 4. Course runs page

4.6. *Individual Courses run a page*

The individual course page contains the course name, course id, and course status (archived or current). If the

course is archived, the page header displays on an orange background, and if it is currently a running course the header background displays on a green background. This is followed by an interactive grade chart with two data sets (passed and failed). One data set can be disabled if needed for more clarity. Next, the average points for each subsection with possible maximum points.

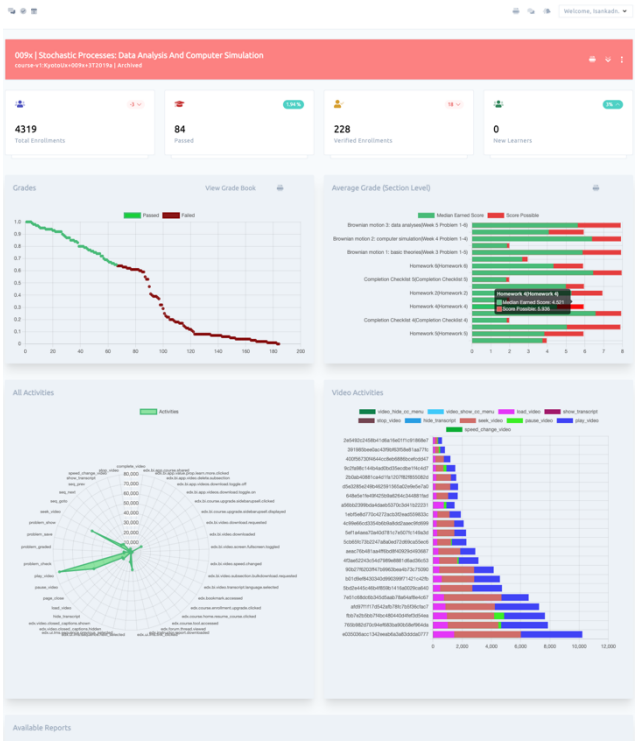

Figure 5. Individual course page

4.7. Instructors

The instructors' page displays a set of cards of all instructors that offer MOOCs at KyotoUx. Each card contains the instructor's photograph, name, title, affiliation, and the number of course runs. There are also quick links to their courses on edX, the instructor's website, and edX profile. Cards are clickable and linked to the individual instructor page. This contains a summary card of each course run of their course(s) and an interactive multi-dataset chart.

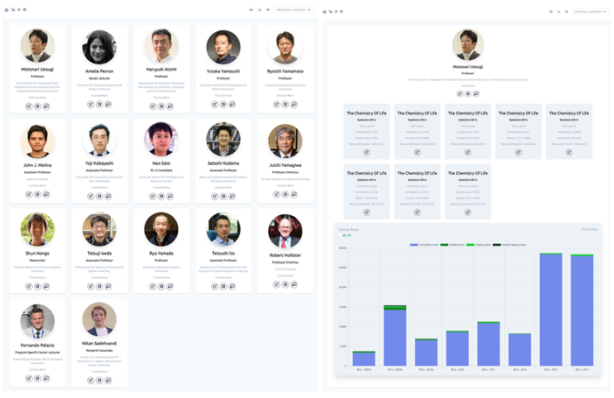

Figure 6. Instructors page and instructor page

4.8. Calendar

Technically we are using Google calendar which is integrated with KMP (v2) using Google Calendar API. It is simple but provides valuable insight to know the current running courses at any given time or period. That is where the calendar page comes in handy. It is automatically updated with each data pull request. Additionally, the MOOC team can create an event from this page if they want.

Figure 7. Calendar page

4.9. Report

On the report page, we can generate a report for a selected period, primarily used to generate individual course reports and KyotoUx by academic year. Apart from these generated reports, a print function is enabled for all charts and tables and all pages themselves are print-friendly and can be printed as a quick report.

4.10. Notifications

Most Kyoto University courses are offered year-round in a self-paced manner, and the notification tool keeps us informed of critical course dates. It's a simple component built mostly around email communication. It sends out a simple email message containing the course's start, end, and special dates, as well as what to watch for.

5. System Architecture

System architecture ensures that different requirements and numerous guidelines are met in the system's delivery. We have considered our unique requirements with university guidelines and industry standards. We prefer to use the best, most popular, and well-maintained open-source software tools and frameworks for KMP (v2) as it gives several advantages including fast development, freedom and flexibility, low cost, and ease to publish our work as another open-source project.

KMP (v2) has been designed and developed to deploy in a Linux environment and we are using the Ubuntu Operating System (OS) to run KMP (v2) in production settings.

As the system addresses sensitive and protected data packages we have designed the system to work with minimum human involvement, especially for data gathering, filtering, and analysis. The data pipeline and display dashboard are the two main components in KMP (v2) (Figure 1). The data pipeline handles three types of data

streams and provides an end-to-end secured high-performance data solution to the KMP (v2) dashboard.

The dashboard backend is developed using a mainly Python-based Django web framework [11] that provides a complete high-performance and robust Model-View-Controller (MVC) [29, 30] web development environment. For the front-end, we have used standard front-end technologies HTML, CSS, and JS provided by Django template engine with Tailwind CSS[12], a utility-first CSS framework, Alpinejs [13] lightweight JS framework, and Chartjs[14] simple yet flexible HTML JS charting library for charting.

KMP (v2) contains three types of datastores. The data that takes more resources and time to process are preprocessed during the edX data pull and stored in JSON files in a secure location for quick use of the dashboard. We needed a simple yet secure mechanism to analyze and validate each request in KMP (v2) that was associated with Protect Static Files (PSF).

Nginx X-Accel (Figure 8) is a great feature that manages internal redirection based on the header returned from a backend. When an external request bound to PSF is made to the Nginx server, it redirects internally through Gunicorn to the Django backend middleware (Figure 10) to determine whether or not the request is authenticated. If the request is authenticated, it is redirected to the PSF location.

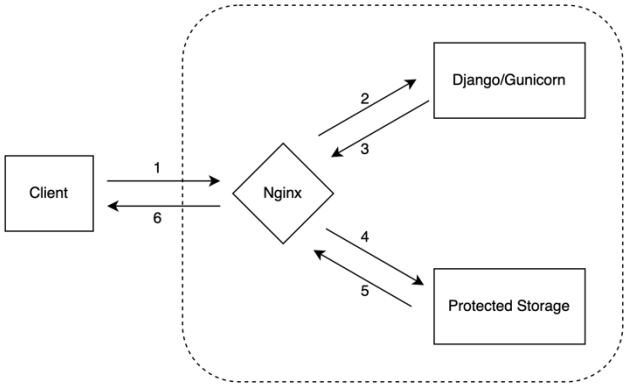

Figure 8. Django and Nginx X-accel-redirect

```
# Django Nginx X-accel protected files redirection
location /protected/ {
        internal;
        alias /home/isanka/kmms_v2/protected/;

}
```

Figure 9. Nginx configuration for x-accel-redirect

```
from django.http import HttpResponse
from django.core.exceptions import PermissionDenied


def redirect_protected_view_1(request, path):
    if request.user.is_authenticated:
        response = HttpResponse()
        # protected path
        response['X-Accel-Redirect'] = '/protected/' + path
        return response
    else:
        raise PermissionDenied()


def redirect_protected_view_2(request, path):
    if request.user.is_authenticated:
        response = HttpResponse()
        # protected path
        response['X-Accel-Redirect'] = '/protected/grades/' + path
        return response
    else:
        raise PermissionDenied()
```

Figure 10. Internal re-direction middleware

```
[sources.tracking_logs_in]
type = "file"
ignore_older_secs = 43200000000
include = ["/var/log/tracking/*.log"]
start_at_beginning = true
read_from = "beginning"

[transforms.tracking_logs_t]
type = "remap"
inputs = [ "tracking_logs_in" ]
source = """
. = parse_json!(string!(.message))
if .username !=""{
.event_time = to_unix_timestamp(to_timestamp!(.time), unit: "nanoseconds")
.course_id = (.context.course_id)
.org_id = (.context.org_id)
.user_id = (.context.user_id)
if .event_type == "play_video"{
   .event_video_id = parse_json!(string!(.event)).id
   .event_video_code = parse_json!(string!(.event)).code
   .event_video_duration = parse_json!(string!(.event)).duration
   .event_video_currentTime = parse_json!(string!(.event)).currentTime
 }
if .event_type == "pause_video"{
   .event_video_id = parse_json!(string!(.event)).id
   .event_video_code = parse_json!(string!(.event)).code
   .event_video_duration = parse_json!(string!(.event)).duration
   .event_video_currentTime = parse_json!(string!(.event)).currentTime
 }
del(.event)
del(.agent)
del(.accept_language)
del(.context)
del(.host)
del(.time)
} else {
del(.)
}
"""

[sinks.tracking_logs_sinks_out]
type = "clickhouse"
inputs = [ "tracking_logs_t" ]
database = "tracking"
endpoint = "http://localhost:8123"
table = "events"
compression = "gzip"
```

Figure 11. Vector configuration file (example)

The second data store stores processed results in a MySQL database that facilitates relational mapping. The third

[11] https://www.djangoproject.com
[12] https://tailwindcss.com
[13] https://alpinejs.dev
[14] https://www.chartjs.org

datastore, the ClickHouse database keeps processed daily edX event logs using Vector. Vector collects edX event log data and transforms it according to the “vector.toml” configuration file written in Tom's Obvious, Minimal Language (TOML). In the Figure 11 example Vector configuration file there are three main configurations; (1). Input source (2). Transforms (3). Sinks. As the sample configuration gets unnecessarily long we have added two sample edX events (play_video, pause_video) for transforms. Transforms are simply shaped data with a set of conditions. We can add any number of transforms in many complex ways[15]. Then we can deliver that processed data to the ClickHouse database as in the Sinks configuration.

ClickHouse is far more effective and efficient than traditional approaches [28]. In addition, it works efficiently with a limited amount of resources. ClickHouse in KMP (v2) takes two (2) milliseconds to execute a simple "SELECT (*)" query for forty-nine million records, and 0.4 seconds to process a "SELECT (*)" query with the "ORDER BY" keyword over the HTTP client.

Production deployment of KMP (v2) is implemented using Gunicorn[16] and Nginx[17] over HTTPS. Nginx handles HTTP requests and if the request is for static files Nginx serves the static file. If the request is for dynamic content then Nginx delegates the request to Gunicorn and Gunicorn processes the request and passes the results back to Nginx and serves it back to the client browser.

6. Conclusions and Future Works

This paper has provided a brief history of dashboards and how it helps in Decision Support Systems (DSS) and relevant learning analytic dashboards. The Kyoto University MOOC dashboard is introduced including, its primary components, and how the relevant data is obtained and handled in particular.

The coronavirus disease (COVID-19) pandemic fortified the foundation of online education. So, education-related management tools and data analytics will continue to play an important role in future education. The KMP (v2) is developed on the back of the experience of KMP (v1, MVP) and in that sense, we aim to develop KMP (v2) in the following areas.

Our study found that many edX partners use some sort of management and analytics tool for their MOOC production process and we think the community will be interested in similar tools. After further testing and cleaning the code, we are planning to release KMP (v2) as an open-source tool with clear documentation.

edX research data package contains many different data points and in KMP (v2) we are still not using all those data points. In the future, we will explore and expand further and will use other relevant indicators.

At this stage, our focus was on smooth data processing and developing different metrics rather than spending time on developing an attractive UI/UX interface. We will continue to bring new UI/UX changes to KMP (v2).

Currently, KMP (v2) efficiently manages and processes data from roughly 300,000 learners from 76 course runs. We would like to evaluate the system on a larger data set.

Acknowledgments

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