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ONLINE VIDEO ARCHIVAL SYSTEM

Building Distributed Systems individual project

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MSc

Tallinn 2023

TALLINNA TEHNIKAÜLIKOOL
Infotehnoloogia teaduskond

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INTERNETIVIDEOTE ARHIVEERIMISE SÜSTEEM

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Tallinn 2023

Author's Declaration of Originality

I hereby certify that I am the sole author of this document. All the used materials, references to the literature and the work of others have been referred to. This document has not been presented for examination anywhere else.

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26.02.2023

Abstract

This document is a project proposal for the individual home project in the subjects "Building Distributed Systems", "ASP.NET Web Applications" and "JavaScript".

The document starts with an introduction, which describes the problem that the project is meant to solve and outlines rough expectations for the end result. The main part of the document is an analysis of various aspects of the project and how they should work. This is accompanied by an ERD (Entity Relationship Diagram), which can be found in Appendix 2 and is designed by taking into account the considerations outlined in the analysis. Finally, the document also provides some sketches and thoughts on the potential UI (User Interface) design and flow of the final web application.

The document is written in English and is 15 pages long, including 3 chapters, 8 figures and 0 tables.

Annotatsioon

Internetivideote arhiveerimise süsteem

See dokument on õppeainete "Hajussüsteemide ehitamine", "ASP.NET veebirakendused" ja "JavaScript" koduse individuaalprojekti püstitus.

Dokument algab sissejuhatusega, mis kirjeldab probleemi, mida projekt lahendama peaks ning toob välja umbkaudsed nõuded lõpptulemuse jaoks. Dokumendi peamine osa analüüsib loodava süsteemi erinevaid aspekte ning kuidas need töötada võiksid. Sellega käib kokku teises lisas leiduv olemi-suhtediagramm, mis kirjeldab süsteemi andmebaasimudelit, mis on disainitud analüüsis väljatoodud kaalutlusi arvestades. Viimaks on dokumendis ka loodava veebirakenduse kasutajaliidese kohta mõned joonised ja kirjeldused.

Dokument on kirjutatud inglise keeles ning sisaldab teksti 15 leheküljel, 3 peatükki, 8 joonist, 0 tabelit.

List of Abbreviations and Terms

| | |
|----------|---|
| Platform | A website on which videos may exist |
| Author | A user on a platform |
| Entity | General term for several concepts being modelled or dealt with in the system being designed |
| API | Application Programming Interface |
| Webhook | A callback function that allows lightweight, event-driven communication between 2 APIs[1] |
| Pub/Sub | A specific kind of messaging service that supports webhooks, among other things[2] |
| ERD | Entity Relationship Diagram |
| UI | User Interface |
| JSON | JavaScript Object Notation |

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1. Introduction

Online video consumption has become an important part of many people's lives in the modern day. With people spending so much of their time watching all sorts of videos, plenty of those videos will likely end up being important and memorable experiences for their viewers. Whether they provide entertainment, educational value or cultural insight, online videos are a form of media, art and even history that deserve to be preserved.

Currently, however, people tend to simply watch whichever videos are fed to them by various websites' algorithms, and then move on. There is no guarantee that these experiences will still exist in a few months or years or decades. The video is still hosted on a platform out of the viewer's control, and might become inaccessible at any time because the author changed the video to private, a copyright holder issued a copyright strike, or perhaps even the entire video platform was shut down.

While there exist some ways to download videos from various online video platforms, they all have their shortcomings and they don't provide any sufficient way to manage the vast amounts of video content that a person might wish to archive over the course of their life. A video platform might not even provide a download feature, or such a feature might be locked behind a paywall or limit what the user can do with the downloaded video. There is usually no provided way to archive the context surrounding the video, such as the comments, or the history of different changes that might have been made to the video or its metadata.

The goal of this project is to create a system that allows its users to conveniently archive videos from supported video platforms. Rather than being one large centralized service hosted by one owner and used by large amounts of users, it's meant to be a project that people can self-host with the means available to them, potentially sharing their instance with a small group of people. Initially the only supported platform will be YouTube, but if time allows, Twitch support may also be added. The system must support both manually archiving specific videos and automatically archiving videos from certain authors or playlists. Archiving a video involves archiving its surrounding context, such as the video's title, description and comments. Usually the video file is also downloaded, though that can optionally be turned off. In addition to videos, the system will also support archiving playlists and authors. When a video, playlist, or author is archived, it will usually also be monitored - this means that the system will keep track of changes made to it and

automatically record those as well.

The second major aspect of the system will be content management and organization. Users will be able to define and assign categories to videos, authors and playlists. They will also be able to give detailed ratings to videos, authors and playlists - in the context of a specific category or not. This will allow users to filter and catalogue their archived videos, video series, subscriptions etc. according to various conditions, as opposed to simply having a pool of content and data without much meaning attached to any of it.

In addition to and using the aforementioned features, the system will provide some enhancements on top of existing platforms. For example, the system will allow users to subscribe to specific playlists. That way, if a user is only interested in specific content from an author, they can subscribe to the playlists that interest them, without being flooded with notifications about other videos. Another enhancement stems from the system's category system, which will enable users to filter their subscriptions by category and see the ratings they've given these authors in the past. If a user is subscribed to hundreds or even thousands of channels, half of which the user doesn't even remember subscribing to, this feature will significantly improve the user's ability to keep track of all these authors, whose content the user likely wishes to keep up to date with. Users will also be able to create playlists that contain videos from several different platforms.

The system will consist of a backend and several frontends. The backend will be written in the C# programming language and contain a library for interfacing with the system's database, which can be used by other parts of the system. The backend will also contain automated monitoring and archival services, which will run in the background and regularly perform tasks necessary for automatic archival and notifications, such as checking for new video uploads or changes in monitored data. There will also be an ASP.NET Core web application that will function as a web-based client for the whole system, but also provide an API interface which will allow for the creation of other client applications. One of these other client applications will be a JavaScript-based web application, which should have full or nearly full feature parity with the ASP.NET Core web application. There are also plans to create a browser extension and a Discord bot to provide some more convenient ways to quickly perform some simple functions with the system, but these are not within the scope of this specific project.

2. Analysis and planning

When specific attributes or entities are mentioned in this chapter, Appendix 2 should be referred to in order to get a better understanding of said attributes or entities.

2.1 Platforms and subplatforms

A platform is any specific location that videos and entities related to videos belong to. One of these platforms is this archival system, but all the rest are external websites such as YouTube or Twitch. However, videos from the same website could belong to a different sub-section of that website. For example, videos from YouTube could be divided into regular videos, shorts, clips, and livestream recordings. Videos from Twitch could be divided similarly. Depending on the platform, there could be a significant difference between how these different types of videos should be treated – they could have different URL patterns, different properties, and even different API endpoints. For this reason, such videos will be treated as being from different platforms. However, in some contexts it may still be desirable to treat all these videos as being from one platform, so such platforms should be defined as subplatforms of a common parent platform.

2.2 Authors and users

This project will use the ASP.NET Core Identity framework to facilitate users, permissions and logging in. A user in this context is semantically different from a user of a video platform, who can upload videos, leave comments, create playlists etc. This becomes apparent as soon as one attempts to define a database entity that would store both of these kinds of "users" – there would be one group of attributes that only pertain to one type of user, and another group of attributes that are only relevant to the other type of user. Thus, it makes sense to separate the two concepts – henceforth the kind of user entity that can log into the archival system will be called a user, and the kind of user entity that is intrinsically semantically tied to video content will be called an author.

However, users of the archival system still need to be able to behave as an author – for example when creating a playlist in the archive. In fact, users should have the ability to act as several authors (in the archival system), which could be used as a means to present themselves with different profiles in different contexts or to further segment and organize their archive library under different identities.

2.3 Entity attributes and nullability

Most of the main archive database entities, such as videos, authors, playlists, and comments have many attributes which are nullable – they might not have a value assigned to them. This is usually due to the following reasons:

- A property that exists on one platform may not exist on another. For example, perhaps some platforms' videos don't have descriptions.
- The value might not be known to the archival system. This may be because the entity itself wasn't accessible – the author's account was deleted or the video was set to private – or because that attribute isn't publicly accessible, like the dislike count on YouTube since December 13, 2021[3].
- The value might actually be empty. For example, a specific video might not have a default audio language set, even if videos on that video's platform usually do.

There are, however, some attributes which aren't nullable. The potential reasons for this are:

- That value is a meta-property assigned by the archival system and is always known. For example the Monitor attribute of the Video entity, which indicates whether the archival system should monitor changes to that video or not.
- That value is always necessary for the entity to even have any meaning in the archival system. A good example of this is the IdOnPlatform attribute, which stores a value that uniquely identifies that entity on its platform. Without that value the system wouldn't even know if that entity has already been added to the archive, and consequently allow for unlimited duplicate entries to be added.

2.4 Subscriptions and polling

Authors can subscribe to other authors. This may mean an author on the archival system subscribing to another author, who can be from any platform. Alternatively, this could mean an author on a platform subscribing to another author on that same platform. In both cases, the archival system will need to monitor the author who was subscribed to in order to be able to notify the subscriber of that author's video uploads. The system must also be able to monitor some other entities, such as videos, playlists and comments in order to update them in the archive if any changes are made to them on their respective platforms.

To accomplish this, the system will use one or both of the following approaches:

- **Polling.** This method involves periodically fetching data about the relevant entity from its platform to see if any changes have been made. The data could be fetched using API requests or using web scraping, depending on the specific platform and entity.
- **Pub/Sub or Webhook.** With this method the archival system will subscribe to a notification feed on the relevant external platform, which will notify the archival system if updates are made to the subject of the subscription. The upside of this is that changes will be received right around the time when they took place, as opposed to whenever the scheduled polling service gets around to checking for changes. However, this method may not be available on some platforms and even if it is available, is usually limited in the sorts of updates it supports. For example, the YouTube API's Pub/Sub only sends notifications when a video is uploaded or when a video's title or description are updated.[4] Since both YouTube's and Twitch's support for this method is author-specific, the archival system's design will also only support storing information about author-specific Pub/Sub subscriptions.[5] Thanks to this, the system won't need to store the subscription feed URL, because it can be constructed from the associated author entity.

Regardless of the specific platform-specific nuances, although this method can be used to receive faster updates for some properties of some entities, use of polling will still be required to cover other entities and attributes and to ensure changes aren't missed in case of a notification not being received despite a relevant change taking place.

In order to receive notifications within the archival system according to a subscription between authors on an external platform, a user of the archival system must be able to give the archival system permission to access their subscriptions on that external platform. To accomplish this and to continuously synchronize these subscriptions, the system will use the `ExternalUserToken` entity. In addition to storing the necessary information for getting subscription data from the relevant external platform, this entity will also provide a way of linking users to these external authors, in order to determine which users should receive notifications about those subscriptions.

2.5 History

When certain types of entities are changed, the archival system shouldn't just discard the previous state of that entity. How a video's title or an author's profile picture has changed over time is an important aspect of these entities' identities. Additionally, some attributes, such as a video's captions, might be an essential accompanying element of the video. In extreme cases, even the video content itself might change. Or, as a less extreme case, a

playlist's composition will almost definitely change as time flows.

All these kinds of changes must be saved into the archive. For each of authors, videos, playlists, and comments, a separate history entity will be used, containing a copy of many of the attributes in its respective original entity. Of course, some attributes will not be stored in the history, such as meta-attributes used by the archival system for monitoring, or attributes which should never change, such as an entity's platform.

Unfortunately this approach does mean that the data that didn't change will be duplicated in the history entities. However, that should be outweighed by the benefits of using such history entities, like the relative simplicity that is provided by treating them as snapshots of an entity's state that contains most of the relevant data inside it. The entities' relationships to other entities still remain with the main, "non-history" entity, which also simplifies matters by not requiring complicated join statements, which might potentially be caused by alternative approaches. And since a history entity will almost always be viewed in the context of its corresponding current entity, the attributes and relationships that aren't stored in the history entity can be accessed without any issues. Furthermore, it's expected that updates to such entities will be a somewhat infrequent occurrence, which lessens the impact of unchanged data being duplicated in these entities yet again.

If an entity's privacy status or availability changes, then that change will be tracked in a separate dedicated `StatusChangeEvent` entity. This is because an entity's privacy or availability changing is, in its nature, a different event from that entity's other attributes changing. Tracking these events separately makes it easy to create a separate timeline of video status changes and provides an entity to reference when notifying users who added that entity of those status changes. Also, such a status change event is unlikely to occur in conjunction with another attribute changing, so this reduces unnecessary data duplication in history entities.

2.6 Queue

The host of the archive system might wish to allow some users to suggest adding new entities to the archive, but not actually add them. Other users might be allowed to add an entity to the archive, but not to schedule it and its contents to be automatically downloaded. These kinds of archival requests should be stored in a queue until they're approved and potentially modified by a user with the authority to do so. This queue will also allow the client that added an item to the queue to store extra information alongside that item. When certain events happen to the queued item or the video, playlist, or author related to it, that extra information can be used to send a notification to the client that added it. For example,

a Discord bot could use it to store information about which Discord user added a video, in order to later notify said user about that video's deletion.

2.7 Services

Many of the system's tasks need to run in the background, without direct user interaction. These should be implemented as separate services that perform their tasks independently. For example:

- A service for monitoring changes to entities and recording them in the archive.
- A service for refreshing external user tokens
- A service for sending notifications to users and authors

2.8 Categories, subcategories and ratings

Categorizing archived content properly is essential if the archived data is to maintain any of its meaning. Most categories will likely be defined by the archival system's users for themselves, but the system will also archive categories from other platforms. Unlike many other platforms, the archival system will allow its authors to assign categories to authors and playlists in addition to videos. Such category assignments should also specify whether or not sub-entities of the assigned entity should inherit its category – if an author who is in a category uploads a video, should that video also be assigned that same category? The system should probably also support sub-categories, for situations where a category only really has a meaning in the context of another.

This sort of extensive category system will allow users to effectively organize and filter videos, authors, and playlists they're interested in.

Another feature for organizing and providing meaning to archived content will be ratings. It's fairly common to allow users of a video platform to rate videos – even if it is with only a down- or upvote. Similarly to categories, the archival system should extend this functionality. Ratings will be applicable to playlists and authors as well. They will use a 5-star rating system with half-star precision. Most importantly, authors will be able to leave category-specific ratings: they might give a playlist a 5-star rating in the "Comedy" category, but an overall 1.5-star rating with no category specified. This will let authors better remember what a certain content creator or piece of content meant to them in the past or even who they were in the first place. To help with this, the ratings should also have an optional comment field.

2.8.1 Games

Games are enough of a big subcategory that they deserve to be recorded separately. If archiving content from a platform like Twitch, where almost every piece of content has a game attached to it, that association must also be reflected in the archive. The archival system will use IGDB¹ as a provider for information about existing games, but it could also allow users to add their own custom games for each video. Also, just in case, the system should support the possibility of a game only being associated with a video for a certain part of that video.

2.9 Notifications

An advanced notifications system is an integral part of the value that the archival system will provide to its users. Rather than having one single notifications feed, users must have the option of filtering their notifications in several ways. Filtering by different categories is essential and if a user has multiple authors related to it, the user should be able to also filter notifications using them.

Finally, when subscribing to an author or playlist, the subscribing author should be able to assign a numeric priority to that subscription, which will be added to notifications caused by that subscription and can then be used to filter and sort notifications according to their priority.

Notifications should also be sent to the user who requested the addition of an entity into the queue, if that entity is deleted or becomes unavailable for some reason.

2.10 Custom objects and localizations

Some attributes, such as a video's title and description, can have multiple versions for different languages and locales. Others, such as information about a video's local files, would need to be a list of custom objects with their own attributes. Since such data can't be directly stored in a database column, the typical approach would be to create a separate database entity for each of them and define a relation between them and the entity they belong to. However, such an approach would require complicated join queries when fetching or operating with the data and might also complicate the situation with history entities. Thus, for the sake of simplicity and because these attributes don't need to have relations with any other entities, these attributes will be serialized using JSON (JavaScript Object Notation) and stored in one database column each.

¹IGDB link: <https://www.igdb.com/about>

3. Web Application UI sketches

This chapter provides rough sketches of some parts of the web applications' pages and page elements, to give a more concrete idea of what should be expected from the final project. However, it should be noted that these are only rough incomplete prototypes showcasing a limited subset of the web application's functionality and will thus likely change significantly over the course of development.

Common to every page in the web application will be a navigation bar at the top of the page. Figure 1 shows a section of the navigation bar with a text input field for quickly adding a video, playlist or author to the archive. There is also a bell icon for accessing the logged in user's notifications, an element for the user to select which of their author identities the user is currently acting as, and finally an element indicating who the logged in user is.

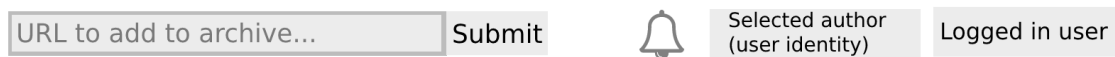


Figure 1. *An image of part of the navigation bar at the top of the web application.*

If the notification bell icon is clicked, the user will see a notifications view. As shown in Figure 2, the notifications view consists of tabs for viewing different kinds of notification feeds, options for filtering the selected notification feed, and the notification feed itself. The user can mark notifications as read or unread and click on a notification to be taken to a relevant page in the web application. The notifications view may end up being a separate web page or it may be integrated into the navigation bar, to pop up upon clicking on the notification bell. This (and other such features) might differ between the JavaScript-based web application and the ASP.NET Core web application, due to some features potentially being difficult or impossible to implement without JavaScript.

Upon clicking on a video upload notification, the user will be taken to the video viewing page. Figure 3 shows what the video viewing page might look like. It should be noted that the view displayed in Figure 3 is showing the video in the context of a playlist that contains the video. This view could be arrived at by clicking on a notification from a playlist subscription or by clicking on a video within a playlist.

Overall, this page is quite similar to the layout of a YouTube video's watch page, containing a video player in the center, with some action buttons and information about the video

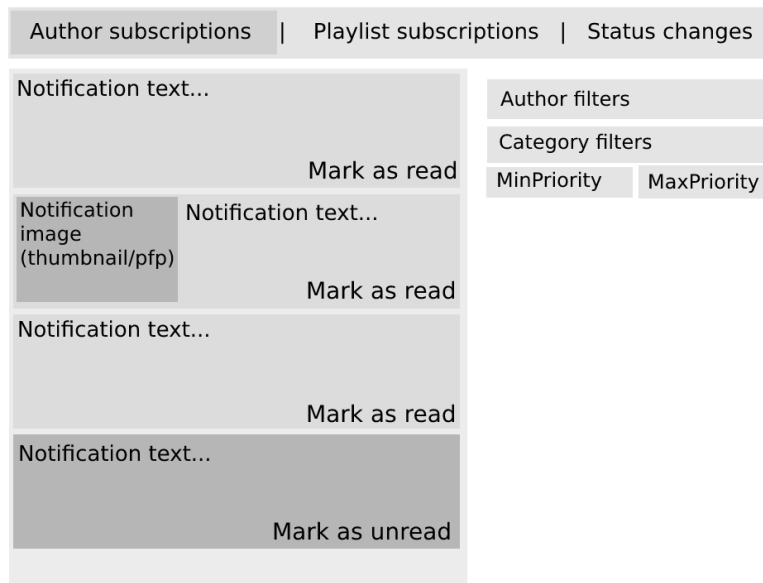


Figure 2. An image of the notifications view in the web application.

and its author below it and comments even further below those. However, there are some additional elements, such as the video's external privacy/availability status, timestamps indicating when the video's information was last fetched from its native platform. The subscribe button has been augmented with a priority option, which will allow the user to set a numeric priority to their subscription. There are also buttons for downloading the video from the archive, viewing the video's change history, selecting whether the video should be played from the archived video file or directly from its website of origin using an embedded video player etc. As was the case with the notifications button, some of these buttons might end up leading to dedicated pages for performing their actions, whereas others could simply function as pop-up menus within the video page. Again, this will likely differ between the JavaScript-based web application and the ASP.NET Core based web application.

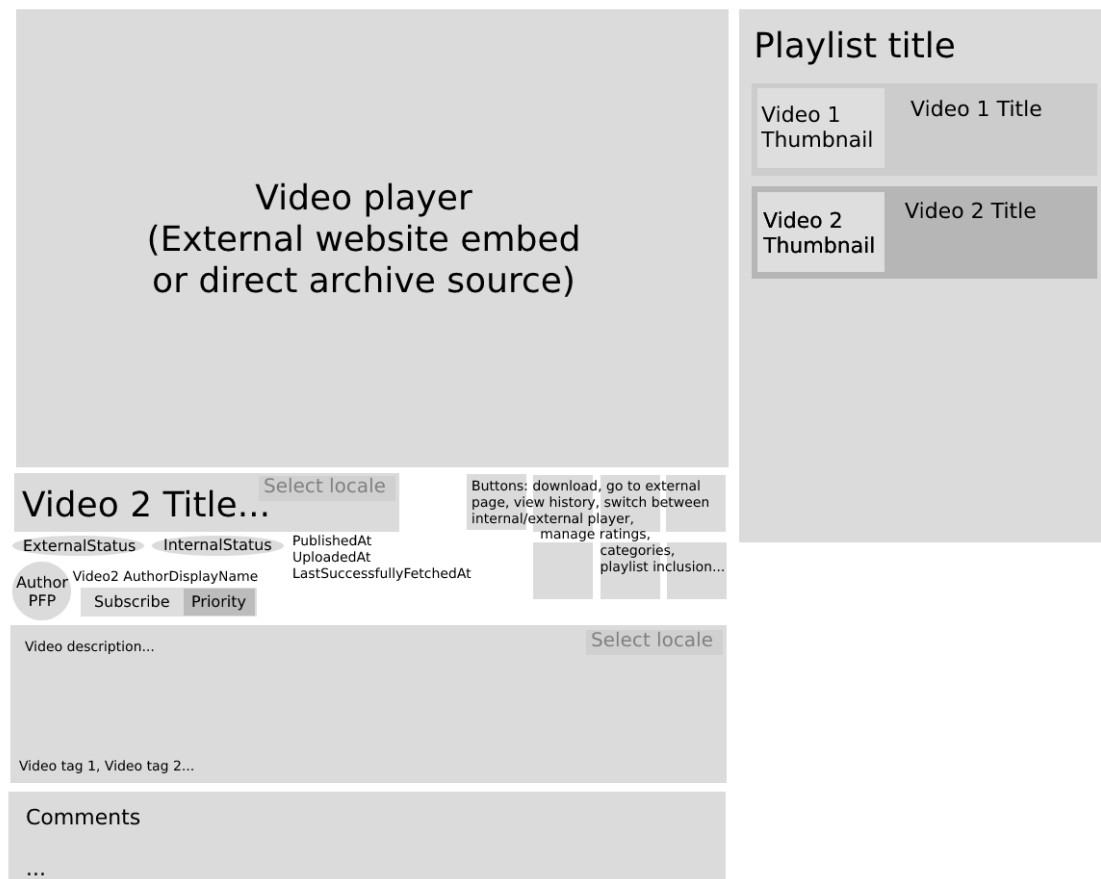


Figure 3. *An image of the main video viewing page in the web application.*

The image in Figure 4 demonstrates what the menu for adding ratings to an entity might look like. Important to note is that it allows for one entity have multiple ratings with each being in the context of a category (although it should also allow adding one rating without a category). There is also an optional comment field. Yet again, this will likely end up being a separate web page in the ASP.NET Core version of the web application and a pop-up menu in the JavaScript-based version.

Subject entity - author, playlist or video

Select Category

Add

☆ ☆ ☆ ☆ ☆

Enter comment...

Category

Update

☆ ☆ ☆ ☆ ☆

Remove

Valuable insight and funny laughter

Figure 4. An image of the view used for managing an entity's ratings in the web application.

Figure 5 features an author page, with its videos section selected. Most of it should be fairly intuitively understandable, however it should be noted that some elements, such as the ones labelled "Category filtering options" and "Sorting options" are simplified placeholders – their implementation details will be determined at a later point and they will probably end up looking somewhat more complex than simple rectangles in the completed web application.

Author profile image

Displayname
 @Username
 SubscriberCount

Subscribe

Priority

Manage Author Ratings

Manage Author Categories

Edit Author

Videos | Playlists

Category filtering options

Sorting options

Video 1 thumbnail

Video 2 thumbnail

Video 1 title
 PublishedAt
 ExternalStatus

Video 2 title
 PublishedAt
 ExternalStatus

Figure 5. An image of the videos section of an author's page in the web application.

In Figure 6 an editable playlist page can be seen. Of note is the way that videos can be moved around in the playlist using a numeric text input field and a submit button for each video. This approach is necessary for the JavaScript-less web application, since a drag-and-drop rearranging mechanism can't be easily implemented without JavaScript. The "Sorting options" element above the list of videos also deserves attention – if a non-manual ordering method is selected, the user shouldn't be able to move videos around anymore, because the ordering will be automatic and thus not customizable.

Playlist thumbnail

Author profile image

Author displayname

Privacy Status

Platform

Subscribe

Priority

Manage categories

Manage ratings

View history

Sorting options

Play all

| | | | | |
|---|-----------------|--------|-----------|--|
| 1 | Update position | Remove | Thumbnail | Video title Video author AddedAt |
| 2 | Update position | Remove | Thumbnail | Video title Video author AddedAt |
| 3 | Update position | Remove | Thumbnail | Video title Video author AddedAt |
| 4 | Update position | Remove | Thumbnail | Video title Video author AddedAt |
| 5 | Update position | Remove | Thumbnail | Video title Video author AddedAt |

Figure 6. An image of an editable playlist view in the web application.

Upon clicking the "View history" button in the playlist view, the user will be taken to the playlist's change history page (demonstrated in Figure 7), where a timeline summarizing changes made to the playlist is displayed. If the changes can be concisely summarized, this summary will be displayed here, as is the case with the first four entries in Figure 7, starting from the top. However, the final visible entry (at the bottom) had more complex changes made and would require the user to click on the "Details" button to see what exactly was changed. Changes in the playlist's availability or privacy status are treated separately from other attribute changes and they can always be concisely summarized, which is why those entries have no "Details" button.

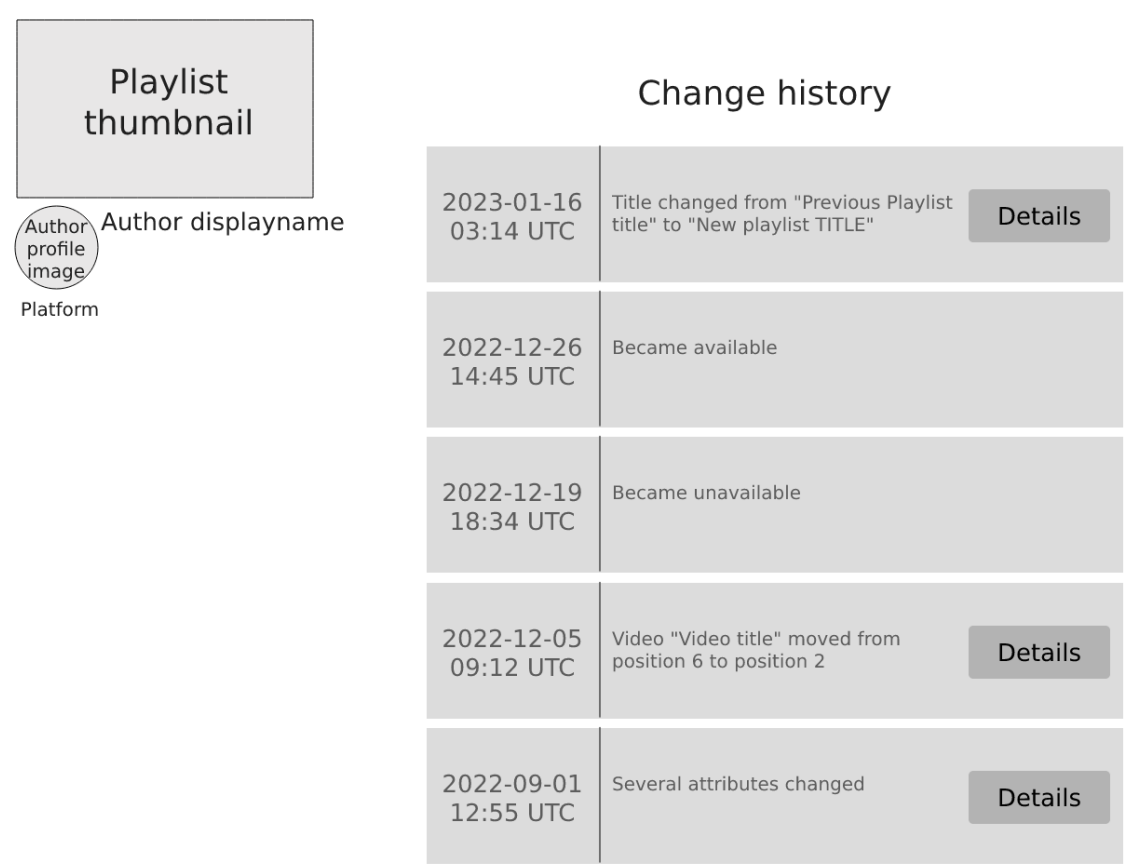


Figure 7. An image of an overview of past changes to a playlist in the web application.

Finally, there must be a way to search for and filter entities in the archive. Figure 8 displays a mock-up of what such a search page might look like for authors. There are options to search for authors by some of their attributes and filter by categories that they do or do not have. This search page and other like it will likely be significantly expanded during the project's development, to allow the search to be as customizable as possible. However, this will also likely cause some complications. For example, if a "search by URL" feature were implemented, it would need significant custom logic, especially since authors can often have multiple URLs, constructed based on different attributes. Searching by a custom-serialized attribute will be especially problematic, but should still be attempted – for example, searching by a video's title, which is a serialized dictionary of localization keys and matching title values, is a feature that would be nice to have.

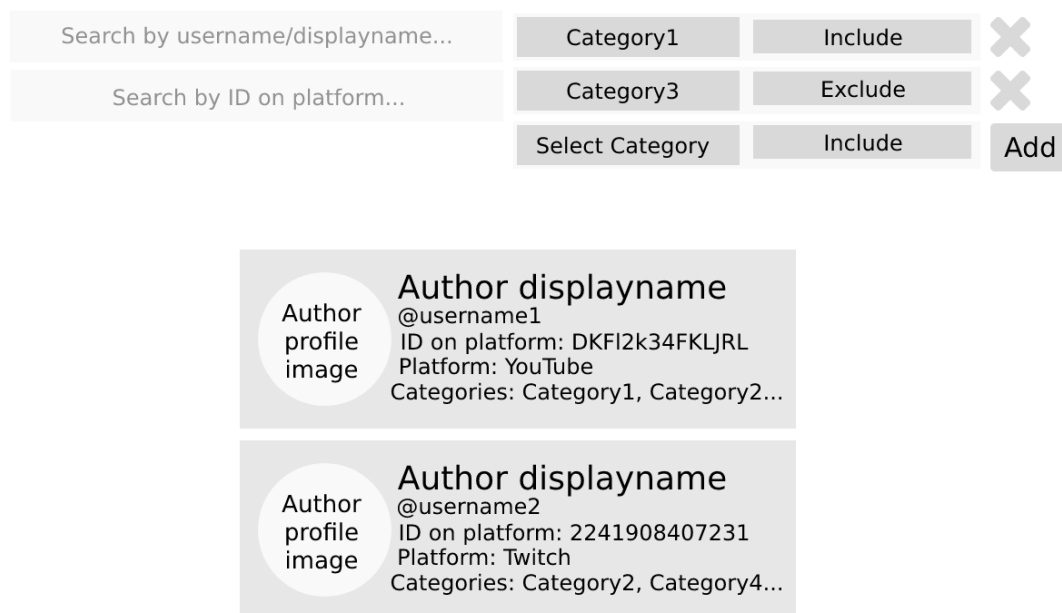


Figure 8. An image of a search page for finding authors in the web application.

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- [4] *YouTube Data API Guides - Subscribe to Push Notifications*. [Accessed: 26-02-2023]. URL: https://developers.google.com/youtube/v3/guides/push_notifications.
- [5] *Twitch API Docs - EventSub Subscription Types*. [Accessed: 26-02-2023]. URL: <https://dev.twitch.tv/docs/eventsub/eventsub-subscription-types/>.

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26.02.2023

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Appendix 2 – ERD

This appendix can be found on the next page, due to its large size.

