vr-mfa Design Document

The Virtual Reality Museum for All

Team Members

Ben Reynolds is a third year undergraduate studying Computer Science at MIT. He worked as the algorithm developer and also as project manager. Ben's primary responsibility was designing and implementing the museum floor plan generation algorithm. He also coordinated the group in creating the final paper and presentation

Harihar Subramanyam is a third year undergraduate studying Computer Science at MIT. He worked as the server-side developer and also as project manager. Harihar built the scraper, room generation code, the software for generating the museum from the floor plan/rooms/paintings, the API exposed to Cardboard, and the code for persisting data to the Redis cache and PostgreSQL database. He also deployed the server, created the pitch presentation, and organized/led meetings.

Val Healy is a third year undergraduate studying both Comparative Media Studies and Women's and Gender Studies at MIT. She worked as a developer/designer on the Google Cardboard side and also as researcher. She assisted in writing the code for the virtual reality museum on the Cardboard and made design decisions to improve the user experience. In addition, Val led the research effort to understand curation practices and notions of quality in existing institutions.

Zach Sherin is a fourth year undergraduate studying Computer Science at MIT. He was the lead developer on the Google Cardboard side. He was responsible for building the infrastructure of the Cardboard app, implementing the movement system, integrating it with the server, and improving app performance.

Abstract

The vr-mfa is a virtual reality art museum which is randomly generated every day and whose pieces are randomly selected from the online amateur art community, DeviantArt. It aims to democratize museum display space and to both be a place for Deviantart artists and users to admire the work of the community. This project was inspired by the following observation: Since museums have limited space in their galleries, curators must judge which pieces are displayed, and this tends to favor professional artists. So, the vr-mfa aims to complement traditional museums by creating a new virtual museum every day (to address the issue of limited space), catering to amateur artists, and using randomization to reduce human bias when

selecting artwork. Through this, vr-mfa hopes to encourage museums to think about alternative approaches to curation, about techniques for presenting artwork, and about the amateur artist community.

Background Research

Art institutions operate using a rubric of quality and prestige in their choosing of which art to display. This- more often than not- denies amateurs the opportunity to showcase their artwork in a museum setting.

Our research has shown that it is not just amateurs who are barred from art institutions. These institutions have a long history of discriminating against all varieties of artists who belong to marginalized groups.

The article “Are You Qualified?” by Marissa Vigneault shows how constructed perceptions of the style and quality of women’s paintings’ in relation to men’s paintings have been used to exclude women’s art from galleries. Others, such as Schávelzon and Zorzi, have shown how racism and colonialism have played a role in museums’ collections, either by exclusion or theft.

In addition, Margaret Mettler discussed how graffiti and other street art, types of public art typically practiced by the poor and working class, are criminalized; this stands in contrast with art institutions, which are sanctioned spaces for art exhibition.

In some sense, the museum could be said to be a boundary of art. Within the boundary, art is allowed, but outside, it is criminalized, especially when practiced by the most marginalized in a society.

In addition to our journal research, we also researched previous virtual reality museum projects and groups. We found three: “Foundation of the Hellenic World,” “Europeana: Museum of the Future,” and the “Museum of Stolen Art.”

The first, the Foundation of the Hellenic World is a project celebrating historic Greek culture. The group produced two virtual reality projects. Their ImmersaDesk allows users to view a 3D map on a desk with a virtual reality headset, and their ReaCTor project allows users to manipulate a wand and a virtual reality headset to traverse through virtual landscapes in Greek history.

Europeana: Museum of the Future, designed by the Europeana online collection of digitized art, is a virtual museum of some of the group’s digitized art. Its purpose is to

provide a virtual reality museum environment, accessible through the Oculus Rift virtual reality headset, to view art that has already been shown in museums.

The last, the Museum of Stolen Art, is a virtual museum populated with digitized versions of paintings that have been stolen. This museum gives users the opportunity to view works of art that would be impossible to view in a museum, for virtue of being stolen.

These ideas and projects have influenced our design process. Our museum will source art completely randomly, disallowing much of the biased and oppressive potential of traditional curation. Furthermore, we will source art from DeviantArt, which is accessible to a large range of people, though there are still barriers to access of the site (mainly, Internet and scanner access, as well as the skills to use these technologies). Nevertheless, the art that is on the site is nearly all done by amateurs.

Project Development and Process

The vr-mfa consists of three areas.

First is the museum generation algorithm, which is responsible for building a digital representation of an art museum.

Second is the vr-mfa server, which is a software suite consisting of the scraper, museum generator implementation, database, cache, and API.

Third is the app for the Google Cardboard, a cheap virtual reality headset, which renders the generated museum and allows the user to explore it.

The development in each area is described below.

Museum Generation

There are three steps in museum generation - floor plan generation, interior room generation, and painting selection. Of the three, floor plan generation is the most complex.

Step One: Floor Plan Generation

A group meeting was held to define the floor plan structure and brainstorm an algorithm that could generate a floor plan.

Initially, the goal was to allow arbitrary shaped rooms in the floor plan, but this would make rendering rooms in the Cardboard app very complex, so it was quickly abandoned.

Instead, Zach proposed that the floor plan be modeled as a set of square “slots” placed on a grid. Each slot represents a museum room, and has between one and four doors to adjacent rooms, which may be on the north, east, south, or west walls. This would greatly simplify rendering in Unity.

Ben led the discussion about the algorithm. Slowly, the team converged on an algorithm that would begin at a room at the origin and continue generating rooms radially outward. After the algorithm had been outlined, Ben formalized it, handled edge cases, and implemented it. The final algorithm is the following:

To generate the floor plan, the algorithm randomly selects the number of slots it will use for the museum - call this the “slot limit”. Then, it places a slot at the origin with one, two, or three doors to adjacent rooms. Next, the algorithm randomly selects one of the doors and creates an adjacent slot (with one, two, or three doors) to the origin.

This process of randomly selecting an unused door and creating an adjacent slot continues until the number of slots hits the slot limit. At this point, any doors which do not lead to an adjacent slot are removed, and the floor plan is complete.

This process results in a unique shape for each museum floor plan, which means visitors will move through each museum in a different pattern, rather than become accustomed to the flow of a static floor plan. A sample floor plan is shown in Figure 1.

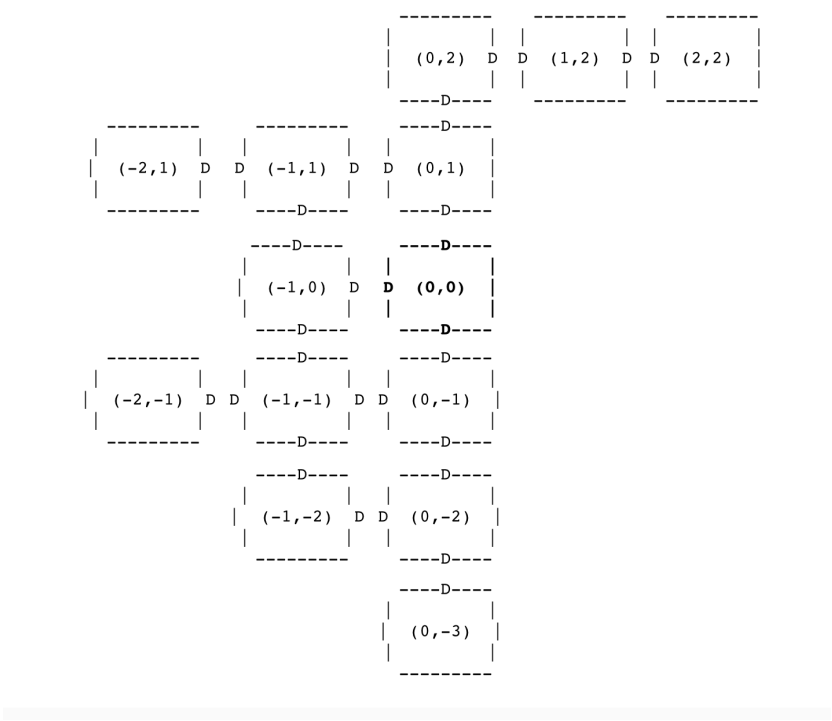

Figure 1: Sample Floor Plan (D indicates door)

Step Two: Interior Room Generation

The group met to discuss how a room would be filled with paintings. Recall that the floor plan consists of square slots. Each slot would contain a room. Zach proposed that a room consist of between one to four doors and set of walls, and that each wall have a painting in its center. The walls (line segments inscribed in the square) would allow more exotic shaped rooms, which overcomes the limitation that each slot in the floor plan is a square. An example room is displayed in Figure 2.

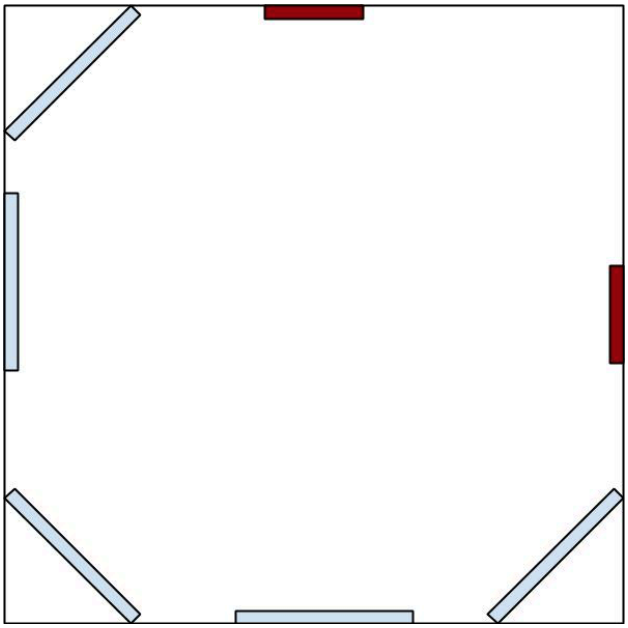

Figure 2: Sample Room (blue lines are walls, red lines are doors)

Then, Harihar determined that there are precisely five possible arrangements of doors in rooms (one door, two doors adjacent, two doors opposite, three doors, four doors) that can be rotated to create any possible room. Call these five arrangements of doors the “basis rooms”. Harihar developed an algorithm to identify and rotate the appropriate basis room for any given slot of the floor plan.

Harihar constructed a set of customized basis rooms (i.e. copies of the basis rooms with different arrangements of paintings) and the software to generate, persist, and select from them. He then implemented the algorithm to populate the slots of the floor plan with the appropriate rooms. The algorithm is described below:

In order to populate the floor plan, each slot in the floor plan is considered in turn. One of the customized basis rooms with additional walls is randomly selected, rotated appropriately so that the doors match the floor plan, and is placed into the given slot of the floor plan. This repeats until all the slots in the floor are filled with rooms.

Step Three: Painting Selection

While the team was refining the pitch and while the museum generation algorithm was being implemented, Harihar built a scraper to fetch images (with their associated titles and authors) from DeviantArt every few seconds (the scraper is discussed in greater detail in the following section). Once the floor plan generation and room generation algorithms were complete, Harihar integrated them with the scraper to populate the museum with paintings. The algorithm is described below:

The scraper accumulates a random set of images. Each wall of a room is defined to hold a single image, so the final step of museum generation consists of choosing which image to place on each wall. The algorithm iterates through each wall and randomly selects an image to place on the wall. This is repeated until all walls are filled with images.

Server

Harihar built the vr-mfa server, which is a set of Python scripts that implement the required operations for creating, persisting, and serving museums. The architecture of the server is shown in Figure 3:

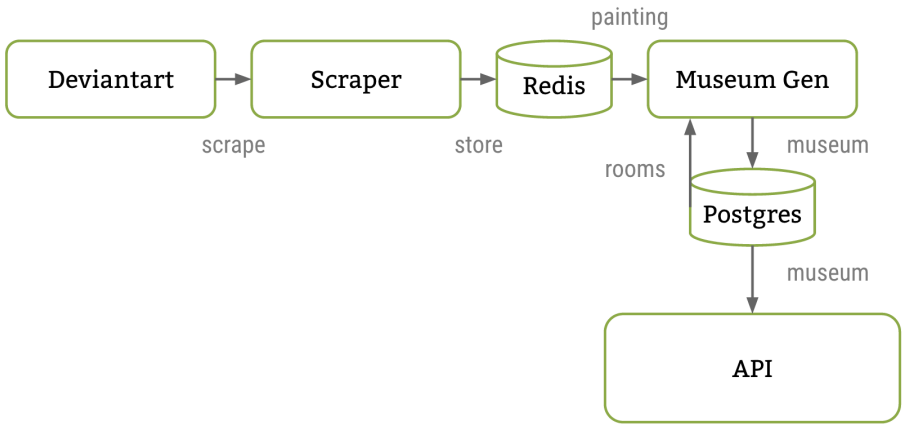

Figure 3: Server Architecture

First, Harihar built the scraper, which is a script which fetches a random page of the DeviantArt archive every few seconds, scrapes the images (as well as their respective titles and artists), and persists them in a Redis cache (an efficient, in-memory data store). The server imposes a limit on the size of the Redis cache. Before adding the most recently scraped set of images to the cache, some images may be randomly evicted to respect the limit. This ensures that the cache does not grow too much and that every image in the archive is about equally likely to be in the cache. Note that there is no reason to persist the image set on disk because a new image set can be rescraped in a matter of seconds (thus, vr-mfa uses a cache instead of a database for the image set).

Ben wrote the museum generation script which implements the museum generation algorithm. Harihar created the basis rooms and their associated walls and stored them in a Postgres database. He then combined this with Ben's museum generation and the

scraper to create the script that generates a museum and persists into the Postgres database.

Finally, Harihar wrote an API (using the Python Flask library) which serves the day's museum. Museums are generated lazily. That is, the day's museum is only generated and stored in the database when a client makes an API call (further API calls for the same museum are satisfied by reading from the database).

Cardboard

As Ben and Harihar worked on the server, Zach and Val worked on on the Cardboard app. The app is a game written in the Unity3d game engine that allows users to experience the museum generated on the server.

Initially, Zach and Val built the app to generate a museum from a static file (the server was still under development). Once the server was complete, they integrated the app with the server.

First, the app calls up to the server to download the museum file for the day, and then downloads each image for the paintings on the wall. The user places their phone in the cardboard headset, and is treated to a first-person view of the museum. By pressing the magnet on the side of the cardboard headset, the user can move around the museum and find look at each of the paintings for as long as they wish.

Zach worked to improve the movement controls so that they are more intuitive for the user, and he also improved the performance for image downloads.

Originally, the museum was going to have a sketched-in, architectural drawing style. However, this approach was abandoned because it proved to be difficult to implement and because Val was able to generate an appealing rendering of the museum with hardwood floors and a new set of wall colors, This showed that creating a more realistic museum was indeed technically feasible.

Enabling Technologies

Cardboard

The Cardboard app runs on an Android phone (Google Nexus 5 handset).

The Cardboard itself is a cheap virtual reality headset made out of cardboard. It allows the phone sit inside it.

The app is developed using the C# programming language in Unity3D (a game engine). This is then compiled into the native Android app.

Backend

The backend is written in Python and uses a number of different technologies.

The scraper uses the Beautiful Soup library to scrape images from DeviantArt. It persists the images in a Redis cache.

The museum generation consists of software for floor plan generation, room generation, and painting sampling. It persists rooms and museums in a PostgreSQL database.

The API uses the Python Flask library to expose API endpoints. It returns the museum data as JSON.

All the server code is deployed on an Ubuntu 14.04 virtual machine on DigitalOcean.

Journey Map

The vr-mfa project is designed to be a more engaging way to view digital art than one typically experiences on the Internet. This is enabled by recent advances in virtual reality technologies, which offer an immersive first-person view into a virtual 3D world.

To enter into our 3D world, the user must first install our app onto their Android phone. This can currently be done by connecting the phone to a computer, and moving the application file onto the mobile device, but in the future we could distribute the app via other channels such as Google Play.

After installing the app, a user must launch the app and insert their phone into a Google Cardboard headset. The user then holds the Cardboard to their eyes, and is now ready to start interacting with the project.

Figure 4: Google Cardboard Headset with Phone

After a brief duration of waiting, while the phone downloads the most recent museum from the server, the user will see themselves surrounded by a virtual museum environment. They are standing in a room with hardwood floors and paintings hanging on cream-colored walls. In the distance, they can see more paintings displayed in adjacent rooms. When the user turns their head in real life, the phone detects the motion and rotates the user's perspective within the 3d world to match their head movement; in this way, the user feels as if they are really inside the 3d museum environment.

To walk around the indoor space, the user presses a magnetic button on the side of the Cardboard, which causes them to slowly move forward within the virtual museum. To turn, the user simply looks in a different direction, and the movement follows their gaze. To stop moving, the user simply presses the magnet again.

The user is not presented with any instructions, nor are they restricted to follow a certain path throughout the museum. Instead, they are free to wander through the museum from room to room in any way they choose, taking any path and spending as much or as little time as they please in a given location.

Users naturally approach the "paintings" hanging on the walls, but may be surprised at first to see that these are not the typical paintings one might expect at a museum.

Instead, each image is randomly sourced from DeviantArt, and may range from an anime character, to a landscape photograph, to a sketch of an animal, to fan-art of a recent game or movie, or anywhere in between. Occasionally the art may be of a similar caliber as one would expect to see in a traditional museum, but more often the art is clearly the work of amateurs. Regardless of its quality, all artwork is displayed in the same way and given the same significance within the museum. A plaque adjacent to each piece of art gives credit to its artist.

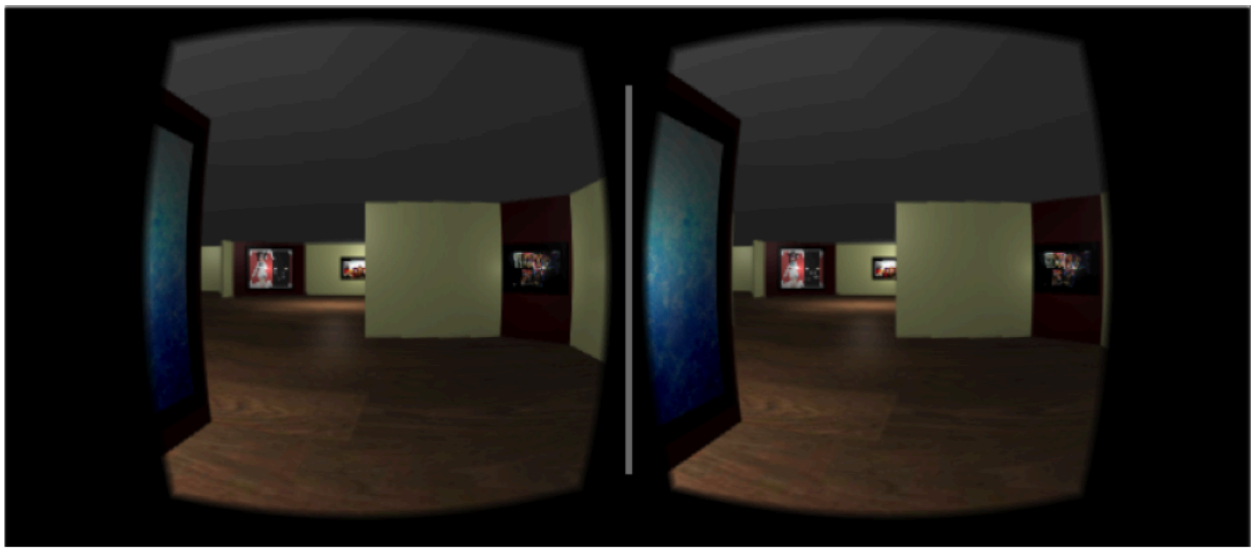

Figure 5: A Museum in the vr-mfa

The user continues to wander and browse the museum until they decide to stop. Each museum is of a finite size, as described by our museum generation algorithm, so the user will eventually exhaust their viewing options if they explore the museum for long enough. We expect most users to spend somewhere between 5 - 20 minutes perusing a single museum.

An overhead view of one possible museum is displayed below (note that this vantage point is not accessible to the user). The user can explore this museum for as long as they desire.

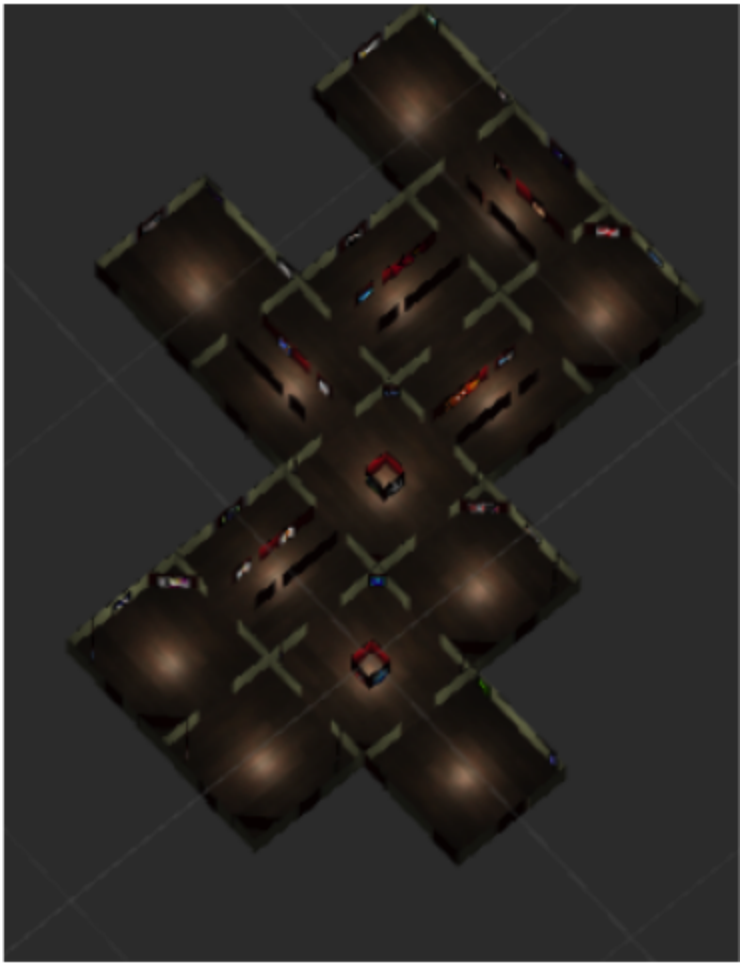

Figure 6: Overhead View of vr-mfa Floorplan

When the user decides that they have seen enough, they simply take the Cardboard headset away from their eyes and close the app.

Because our system generates a new museum each day, this user is encouraged to launch the app again on a subsequent day to experience a new set of artwork. In addition, the floorplan is also randomized each day, so the user will never tire of navigating the exact same museum layout. This adds a level of novelty to the app every single day a user launches it, which helps to retain users and encourage repeat visits.

Future Directions

The current progress in vr-mfa provides all the required features. However, there are a number of steps which can be taken to improve the quality of the generated museums as well as to add new features.

Museum Generation

While the randomness in museum generation allows a great variety in each day's museum, there are still some more opportunities for variety. For example, decorations such as plants and benches may make the rooms appear more realistic. In addition, it is not possible to place one image above (vertically) another. It is possible to place them next to each other by creating two short walls adjacent to each other. Finally, rooms are all the same color, which can be monotonous. Increasing the variety of architecture and color schemes would improve the overall aesthetic experience for visitors.

Server

The scraper only scrapes the image, title, and author, but there are a set of tags associated with each image on DeviantArt. A richer scraper would scrape these as well.

The variety in room types is dependent on the database of basis rooms and their walls. Since these are manually created, it is important to create more in order to improve museum variety. Finally, the API can be easily extended to retrieve past museums instead of just the current museum.

Note that the vr-mfa does NOT aim to allow users to create their own museums nor to use any sort of intelligent (i.e. beyond simple random sampling) painting selection. It is very hard to remove human bias from these approaches, so adopting them may jeopardize the goals of the vr-mfa. Since the DeviantArt archive is very large (over 200 million pieces), the probability that artwork is repeated within a museum is very small.

Cardboard

Currently, we only support images pulled from the Internet. However, we hope that with more time, the museum might be able to support music, 3d models, and other types of art that are displayed online. The more diverse the museum can be, the more rich and rewarding the museum experience will be.

Aesthetically, we also would like to add more furniture and a more fitting pallette for the colors of the walls to make the museum more pleasant to wander around. While these may seem like small tasks, the difference color and a unified aesthetic make in the museum experience cannot be overstated.

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