Supporting a Crowd-powered Accessible Online Art Gallery for People with Visual Impairments: A Feasibility Study

Nahyun Kwon¹ · Yunjung Lee¹ · Uran Oh¹

Received: date / Accepted: date

Abstract While people with visual impairments are interested in artwork as much as their sighted peers, their experience is limited to few selective artworks that are exhibited at certain museums. To enable people with visual impairments to access and appreciate as many artworks as possible at ease, we propose an online art gallery that allows users to explore different parts of a painting displayed on their touchscreen-based devices while listening to corresponding verbal descriptions of the touched part on the screen. To investigate the scalability of our approach, we first explored if anonymous crowd who may not have expertise in art are capable of providing visual descriptions of artwork as a preliminary study. Then we conducted a user study with 9 participants with visual impairments to explore the potential of our system for independent artwork appreciation by assessing if and how well the system supports 4 steps of Feldman Model of Criticism. The findings suggest that visual descriptions of artworks produced by an anonymous crowd are sufficient for people with visual impairments to interpret and appreciate paintings with their own judgments which is different from existing approaches that focused on delivering descriptions and opinions written by art experts. Based on the lessons learned from the study, we plan to collect visual descriptions of a greater number of artwork and distribute our online art gallery publicly to make more paintings accessible for people with visual impairments.

Keywords Art painting · Visual impairment · Explore-by-touch · Image understanding

1 Introduction

People with visual impairments (PVI) are interested in enjoying artworks as much as sighted people [15, 16]. However, they often face accessibility issues when appreciating artworks. For example, most of accessible artworks require them to physically visit certain museums which provides accessible art [4]. Although a number of museums have been providing audio descriptions of exhibited artworks to visitors, they rarely considered the fundamental requirements of PVI such as a detailed visual information of the artworks [33].

To better support PVI to appreciate artwork, a number of studies have been conducted [6, 19, 33, 40]. For instance, Eyes-Free Art [33] was proposed to provide PVI with on-site assistance at a museum with various types of audio feedback depending on the distance between a user and the painting that is in front of the user. Iranzo Bartolome et al. [19] also investigated 3D-printed multi-modal paintings, including both audio and tactile feedback to enable PVI to explore and listen to paintings by touch. While promising, experiences with these existing approaches are limited to a very few selective custom-made artwork replicas that can only be accessed at certain physical exhibition sites. To provide easy access to relatively a greater number of artwork as possible for PVI, another prior study by Kwon and Oh [21] has proposed a web application for touchscreen devices that allows PVI to explore a selected painting by dragging their finger to different objects of the painting displayed on a screen while listening to verbal descriptions of the touched locations. Although their ultimate goal was to enable PVIs to explore a variety of paintings with object-level descriptions without having to visit certain locations for exploring accessible replicas of the limited number of artwork, collecting the required in-
formation for individual paintings is not scalable with a small number of art experts. In addition, it is unclear whether the existing approaches of conveying encyclopedic and/or visual knowledge of artwork can lead PVI to genuine appreciation of artwork.

Thus, this work aims to improve the accessibility of a greater number of artwork for people with visual impairments by enabling them to access artworks online with their touchscreen devices. Our key research questions (RQ’s) include:

- **RQ1.** How can we increase access to a greater number of various artwork for people with visual impairments?
- **RQ2.** To what extent, can touchscreen-based artwork exploration support independent artwork appreciation process for people with visual impairments?

To address the first question, we focused on collecting object-level artwork descriptions from people who do not necessarily have art-related expertise. Inspired by WikiArt\(^1\) which is a visual art encyclopedia following the Wikipedia model\(^2\) powered by collective intelligence.\(^3\) We asked anonymous crowd, Amazon Mechanical Turk\(^2\) (MTurk) workers, to perform annotation tasks of 8 different paintings and analyzed the results to assess the feasibility of this approach. As for answering the second question, we designed and implemented a prototype based on Shneiderman’s Visual Information-Seeking Mantra \(^4\) (i.e., overview first, zoom & filter, details on demand). We then conducted a user study with 9 PVI where participants were asked to explore artworks using our prototypes and answer a set of the representative questions that are asked for each of the four steps in Feldman Model of Criticism \(^5\) (i.e., description, analysis, interpretation, judgment), which is widely used for practicing artwork appreciation \(^6\) \(^7\) \(^8\).

The findings of two studies suggest that an anonymous crowd who may or may not have expert knowledge in art is capable of producing visual descriptions of paintings and that our system enables PVI to appreciate and interpret paintings independently as opposed to passively listening to other’s descriptions and opinions without having their own judgment and appreciation.

The key contributions of this paper are as follows: (1) a confirmation of the feasibility of collecting visual descriptions of artworks from an anonymous crowd, (2) a proposal and implementation of a system that enables people with visual impairments to appreciate various artwork independently on their personal touchscreen-based devices, (3) the qualitative assessments of our system in terms of Feldman Model of Criticism and (4) design implications for supporting an accessible online art gallery for people with visual impairments.

## 2 Related Work

Our study builds upon prior studies in the areas of image accessibility for PVI focusing on artworks.

### 2.1 Making Images Accessible on Web

Various studies have worked on improving the accessibility of visual information of images on the web for PVI by providing alternative text (also called alt text) \(^24\) \(^26\) \(^89\) \(^11\) \(^43\). For instance, Zhong et al. applied the Human-in-the-Loop approach to identify images on a web page that are worth generating alt texts unlike decorative images \(^43\). Winters et al. \(^11\) also proposed an auditory display for social media platform. It provides non-speech auditory icons describing the genders and expressions of any faces in a photo while playing nonvocal background music to convey the overall mood to people who use screen readers. Twitter AI1ly \(^24\) suggested an end-to-end system that creates and retrieves the alt text for Twitter images using a browser extension and crowdsourcing. BrowseWithMe \(^29\), which is a screen reader system specific for shopping websites for clothes, allows PVI to query for information of a product such as price and material using voice input based on the content extracted from a source code of a specific shopping website using its natural language processing module and uses image processing and computer vision techniques to automatically generate a description of the entire outfit given a product image. Similarly, Morris et al. \(^28\) proposed a mobile interface that provides screen reader users rich information of visual contents prepared using real-time crowdsourcing and friend-sourcing; users can listen to not only the alt text of an entire photo but also can drag their fingers over different areas of a photo to listen to information specific to the region that is being touch and ask questions using voice input. EyeDescribe \(^34\) suggested an image labeling system that combines an eye gaze data and a spoken description of the gazed object. It enables the user to explore a spatially annotated image using a touchscreen based application. While these systems relied on automatic approaches to generate visual attributes of various types of images that PVI may encounter while performing web-based tasks (i.e., shopping for clothes and browsing photos posted on social media), automating the same process

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\(^1\) https://www.wikiart.org

\(^2\) https://www.wikipedia.org

\(^3\) https://www.mturk.com/
for artwork is challenging compared to photos of actual products, people or scenes since the visual appearance of the same figure can be different across paintings due to various artists’ expression techniques or materials used for drawing. On the other hand, there is a limited number of masterpieces that we can focus on generating alt texts whereas the number of images on the web increases rapidly. For this reason, we focused on collecting visual descriptions of artwork from an anonymous crowd and explore the feasibility of this approach as the descriptions can be less objective although we expect that the accuracy of automatic segmentation of objects in paintings to improve in the near future. Gonçalves and Marriott [12] already tested creating accessible images by the general public using GraAuthor which is a web-based tool that enables sighted people to create accessible graphics for PVI. Moreover, we also applied the approach of playing location-specific descriptions depending on the touched location on touchscreen-based devices used in a prior work [28] to our proposed system so that PVI can understand the components of paintings as well as locations of specific objects in paintings.

2.2 Making Artwork Accessible for PVI

There are studies proposing various solutions for helping PVI to understand and appreciate artwork. Several museums, for instance, offer audio guides that are accessible to anyone including people who are blind or have visual impairments that play verbal descriptions of exhibited artwork [25, 29, 37, 40]. Similarly, Asakawa et al. [5] also proposed a mobile application that plays audio content of artwork if located closely in front of a user while helping PVI to navigate a museum with its indoor navigation capability. Eyes-Free Art [33] is another example that allows PVI to access different types of audio feedback based on the distance to a specific 2D painting including a sound effect of an object (e.g., a breeze flowing through the grass for a landscape). However, these require PVI to visit certain exhibition sites in person which might not be ideal considering the survey results conducted by Asakawa [5] that almost three quarters of 19 PVI had never been to a museum independently. Making Sense of Art [17] also suggested a new model consists of 3 different ways that enable an independent artwork appreciation of PVI. Moreover, tactile interfaces were proposed to improve image accessibility [14, 6, 19, 3]. Cantoni et al., for instance, proposed a model that performs salient segmentation of 2D art masterpieces to extract the contours of each object segment for 3D printing [6]. A multi-modal 2.5D tactile representations of artwork with a voice command capability was also proposed [19]; a user can ask for specific information about a 3D printed 2.5D painting such as the title or the name of the artist. While most approaches of representing artwork for PVI focused on 2D paintings, Touching Masterpieces [30] created 3D models of famous sculptures which can be downloaded and experienced in a virtual environment with a pair of haptic gloves so that PVI can understand the shape and the size of the sculptures with vibration feedback from the gloves. Rodrigues et al. [35] also proposed computational methodology that creates 2.5D or 3D representations of objects on the artwork so that it enabled PVI to understand the object by its shape and depth. While these tactile or vibration feedback can help PVI to experience artwork non-Visually in addition to audio feedback, limitations still exist as these require PVI to have access to special devices or custom artifacts. Thus, we decided to propose a system that allows PVI to have access to various artwork anywhere through their personal touchscreen-based devices such as smartphones instead of requiring travelling or specific devices.

2.3 Art Criticism Method

Feldman Model of Criticism [11] is the most famous and common method to criticise artwork among art educators due to its simplicity and clear objectives which makes people can easily remember and use the method on their own terms [22]. There are several other methods [21, 32] to criticise artwork that are devised based on Feldman’s model with few minor modification. As described in Table 2 this model consists of only four steps — Description, Analysis, Judgement, and Interpretation — and each step has several clear questions that enables us to know whether we precisely completed the step or not. Moreover, it does not require any former education or knowledge to understand itself. Anyone can easily criticise and appreciate artwork using this method. Since all of our participants barely have prior knowledge about art and most of them have not seen or heard of paintings we used for the user study, we chose Feldman’s model to evaluate their ability to appreciate and criticise paintings using our system.

3 Preliminary Study

Prior to the development of an accessible online art gallery for PVI for providing greater access to a larger number and variety of artwork with the help of collective intelligence similar to Wikipedia, we conducted a preliminary study to investigate the feasibility of collecting descriptions of paintings from a general crowd who do not have expertise in art.
3.1 Method

For this study, we designed an object-level annotation task of artwork and recruited crowd workers to perform the task. We used artworks for this task as shown in Fig. 1. We chose paintings intentionally in pairs varying compositions and genres to explore whether there are meaningful statistical similarities between paintings within the pair or not; A1 and A2 are portraits of a woman, A3 and A4 are portraits of a couple, A5 and A6 are landscape post-impressionism paintings by the same artist (i.e., Vincent van Gogh) and A7 and A8 are cubism paintings by Pablo Picasso.

3.1.1 Apparatus

To collect object-level information and overall description of each of the 8 paintings we chose for this study, we designed an instruction page as well as annotation page as shown in Fig. 2. As for the annotation page, we modified LabelMe [36], which is an online annotation tool to build image databases for computer vision research, so that crowd workers can provide not only the label but also additional information for each object that they have segmented and overall descriptions of the painting that they have worked on. In addition, we enabled Zoom and Fit Page features to help workers easily switch between magnified view and the original image. The interface was implemented through HTML, Javascript, and CSS on our Amazon EC2 server using Ubuntu to be posted for MTurk. It supports various web browsers including Chrome, Firefox, and Safari except for Internet Explorer.

3.1.2 Data Collection Procedure

To collect the object-level as well as painting-level descriptions from crowd workers, we posted our task to MTurk as a HIT (Human Intelligence Task) for each of the eight paintings. Workers who accepted our HIT were given an URL as a survey link of each HIT which would redirect them to our instruction page. The instruction page provides task explanations with visual examples in 3 steps: (1) segmenting objects, (2) labeling and providing descriptive keywords of the segmented objects and (3) providing descriptive keywords for the entire painting.

Step 1. Draw a shape around the object. First, workers were instructed to draw a polygon around an object directly on the presented painting on the screen to specify the boundary of the object with a series of clicks where each click defines a vertex of that polygon as below:

– Follow the boundary of the object it contains with clicks
– A straight line will show up connecting two successive clicked points

Fig. 1: Paintings in our annotation tasks where the labels are numbered from top to bottom and from left to right: (A1) Mona Lisa by Leonardo da Vinci, (A2) Girl with a Pearl Earring by Johannes Vermeer, (A3) American Gothic by Grant Wood, (A4) The Arnolfini Portrait by Jan van Eyck, (A5) The Starry Night by Vincent van Gogh, (A6) Cafe Terrace at Night by Vincent van Gogh, (A7) Guernica by Pablo Picasso, and (A8) Les Demoiselles d’Avignon by Pablo Picasso. Note that the aspect ratio of each painting is adjusted to present all paintings in the same size.

Fig. 2: Example screenshots of annotation pages used in our preliminary study.
Connect the last click point with the first one to complete a shape.

If an object has several parts, please draw a shape for the parts as well as the whole object (e.g., face, eyes, nose, lips instead of just face/hat, umbrella instead of just person).

Note that to collect as many object segments in each painting as possible while keeping the task as simple as possible as suggested by Zhang et al. [42], we showed the segmentation results that were previously performed by others to every worker and asked them to perform the task for the rest of the objects that have not yet been segmented or objects that need to be improved and asked them to segment five objects rather than every object in each painting.

Step 2. Enter object name and visual description of the object. When a worker finishes drawing a polygon of an object, a pop-up window shows up for the worker to enter the label of the object along with at least three keywords for providing visual descriptions as shown in Fig. 2b. Workers were also instructed to annotate whether the object is a part of the entire object or the object has several parts. The specific instruction we provided is written below.

- Enter object name
- Enter a visual description of the object
- Please list at least three keywords that best describe the object (location, color, size, shape, texture, etc.) or the person (gender, age, cloth, posture, facial expression, etc.)
- Please note that there is no correct description. Please write down the words, however you see or feel
- Press the ‘Done’ button
- Enter a visual description of the object

Step 3. Providing descriptive keywords for the entire painting. Finally, workers were asked to enter at least 5 keywords that best describe the entire painting as an option. Workers could start the task by entering their worker ID, which is an unique ID granted by MTurk, and click the ‘Submit’ button at the end of the instruction page, which redirects them to the annotation page. Once workers are done with the annotation task, they can click the ‘Submit’ button at the very end of the annotation page to get a survey code which allows them to get the reward. All of our HIT for each painting was posted on July 27th, 2019 as a survey link project of MTurk. We allocated 20 workers per painting and limited the task execution time to be 30 minutes.

Each worker was rewarded $0.1 per HIT. Personally identifiable data was not collected at all throughout the procedure and the participation in this study was all voluntary.

3.2 Findings

To assess the feasibility of our approach for collecting object-level annotations of paintings from crowd workers, we analyzed our data mainly in terms of reliability and diversity. In addition, we examined the content of the keywords provided by workers to understand how we can better shape the instruction and the design of the annotation task to get informative descriptions in the future.

3.2.1 Content Analysis of Object Annotations

We intended to understand types of keywords provided by crowd workers for each object when no specific instructions were given; thus, we defined 10 categories. We first defined 3 categories which are hue, location and size. Then we defined the rest as an expression that does not belong to any of the first three categories and classified it into the following 7 subcategories: object (mostly another noun words that describe the segmented object), texture (e.g., soft, bushy), shape (e.g., thin, triangular), status (e.g., broken, scared), pose/action (e.g., staring, resting), brightness (e.g., dark, light), and other; see Fig. 3 for more examples per category. For analysis, we developed a custom software written in Python that converts the annotation results in XML into a JSON format. Then, we trimmed every keyword to remove
spaces. Afterwards, one of our internal researchers manually classified each keyword into one of the three categories if applicable. As for the rest, nouns and meaningless words like ‘is’ or ‘not’ were removed and its parts of speech was checked using WordNet from Python NLTK package. For all 8 paintings, the object keywords were the most frequent (23.2%), followed by hue, location, status, other, shape, size, brightness, texture (18.0%, 14.3%, 10.4%, 10.0%, 8.3%, 4.8%, 4.2%, 3.4%, respectively), and pose/action (3.4%).

When examining the proportion of attribute categories per painting as shown in Fig. 4, portraits (A1-A4) seem to have higher percentages of object-related keywords although A6, which is not a portrait, is an exception. As for hue-related keywords, A2 has the highest proportion followed by A6, which indeed are the ones that are most colorful among 8 paintings. Interestingly, A5 has an exceptionally high percentage for location-related keywords. One possible explanation could be that the painting has almost identical objects (i.e., stars) repeated where their location is the most distinctive differences among them. While A5 and A6, which are paintings by the same artist, do not seem to have similarities in terms of the proportion, A7 and A8, two paintings by Pablo Picasso, seem to have some commonalities. For instance, these two paintings have relatively larger proportions of status- and shape-than object-related keywords compared to other paintings. Also, it has a large portion of other category. This could be due to its cubism style as anything that are expressed are mostly abstract and vague. We conducted a Chi-square analysis of independence and found that the proportion of each category differs depending on the painting ($\chi^2_{(63)} = 263.82$, $p < .001$, Cramer’s $V = .16$). As a posthoc analysis, we conducted multiple pairwise comparisons with Yates’ correction using Python’s SciPy library and the results are shown in Table 1.

|     | A1  | A2  | A3  | A4  | A5  | A6  | A7  | A8  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| A1  |     |     | *** |     | *** |     | *** | *** |
| A2  | *** | *** |     | *** | *** | *** | *** | *** |
| A3  |     | *** |     |     | *** |     | *** | *** |
| A4  | *** | *** | *** | *** |     | *** | *** | *** |
| A5  | *** | *** | *** | *** | *** | *** | *** | *** |
| A6  | *** | *** | *** | *** | *** | *** | *** | *** |
| A7  | *** | *** | *** | *** | *** | *** | *** | *** |

Table 1: Posthoc analysis of Chi-square tests for each pair of 8 paintings; ‘*’ is for $p < .05$, ‘**’ is for $p < .01$, ‘***’ is for $p < .001$, and ‘n.s.’ is for results; that are not significant.

Fig. 5: A stacked bar chart that shows the percentages for each of the five attribution categories of overall impressions per painting.

Fig. 4: A stacked bar chart that shows the percentages for each of the attribution categories per painting.

4 http://www.nltk.org/howto/wordnet.html
3.2.2 Overall Impressions

After removing repeated keywords within the keywords provided by the same worker, we collected 408 unique keywords from 106 valid sets across paintings. The average count was 51 (SD = 11.1) per painting. We also examined overlapping keywords from different workers and confirmed that only 153 out of 408 keywords were duplicates, which indicates that 75.7% (N = 309) of unique keywords across workers in total. We further examined the keywords (N = 54) that appeared more than once and found that our workers had the tendency to list the labels or the attributes of the objects (e.g., smiling, old) that appeared in paintings when we asked them to enter keywords that best describe the entire painting. For example, keywords like a woman, girl, earring and couple were the keywords collected for portraits (A1-A4), while the moon, tree, stars were collected for landscape paintings (A5-A6). Moreover, these two paintings had a number of keywords that describe location or the time of the day (e.g., night) of the painted scene. Location-related keywords such as a cafe, outdoor, street were frequently observed especially for A6.

We examined the percentages of each category of keywords; see Fig. 5 for detail. Interestingly, in the case of extremely famous paintings like Mona Lisa (A1), workers entered high-level descriptions about the painting such as the title or the name of the artist and that it is a famous art painting. Again, we conducted a Chi-square analysis of independence and found that the proportion of each category differs depending on the painting ($\chi^2(28) = 110.13, p < .001, Cramer’s V = .26$). A posthoc analysis show that paintings that are grouped together (e.g., A1&A2, A3&A4) are not statistically different. However, A6 is significantly different from A1, A3-A4 and A7-A8. The difference between either A7 or A8 and A2-A3 were also found to be significant.

3.2.3 Descriptive Analysis

A total of 591 objects were annotated in total across 125 workers who has annotated at least one object for all 8 paintings while the rest 35 workers did not complete any annotation at all. However, we examined 528 of them which were annotated by 94 valid workers who completed at least 5 annotation as instructed for the analysis. On average, 66 objects were collected per painting ($SD = 9.5$) and the average number of annotated objects per workers was 5.6 ($SD = 1.3$). In addition, the overall description per painting we collected at the end of the annotation task as an option, 117 descriptive keyword sets were collected across all paintings where the average number of the distinctive keywords per painting was 13.25 ($SD = 1.83$). As for the duration, the time taken to receive 20 workers’ submissions per painting from when HIT was uploaded was 10 hours on average ($SD = 2h 39m$) where the average task completion time per worker was 11m 36s ($SD = 7m 13s$).

3.2.4 Data Reliability Assessment

To assess the reliability of the annotation data collected by crowd, we examined each of annotations and checked for its validity. Two researchers manually examined all the data and flagged invalid annotations given the following criteria: (1) an object is segmented as a single point rather than a polygon with at least three vertices or (2) a polygon is located at a wrong place for its label. As a result, the number of valid data was 408 out of 528, which accounts for 77.2% of data collected by valid workers; five annotations by 3 workers did not meet both first and second criteria while 94 annotations by 24 workers, and 31 annotations by 16 workers were flagged in terms of the first and second criteria respectively.

In addition, we examined validity of annotations created by 31 invalid workers who has annotated less than 5 objects. Among 63 annotations they completed, only 13 annotations which accounts for 20.6% were valid. It is about 56.6% lower than the validity rate of annotations from valid workers. We could find here that the data collected by whom had not followed the instruction is not reliable compared with the data from whom had followed it.

The validity of the descriptive keyword sets describing each of the entire painting instead of objects was also checked; a researcher visually examined the sets and removed improper data (e.g., worker’s unique ID) for MTurk or an URL of the task page. As a result, the number of valid sets for paintings was 106 out of 117 which accounts for 90.6%.

3.2.5 Summary

From this preliminary study, we confirmed the feasibility of collecting object-, and painting-level descriptions from crowd workers, although it requires validity check. In addition, we also identified that object, hue and locations are the most prevalent keywords that crowd workers provide when no specific instructions are given regardless of paintings. Moreover, we found that the workers tend to provide specific types of attributes.

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5 Although we instructed workers to annotate at least 5 objects, it was accidentally set to allow submitting the task regardless of the number of annotated objects.
more than others depending on the paintings for both object and painting level descriptions. Thus, specific guidelines should be provided to workers if one wish to have a balanced number of keywords across categories regardless of the painting type.

4 System Overview

After the preliminary study, we designed and implemented AccessArt, which is a touchscreen-based online art gallery optimized for Apple’s iOS devices with VoiceOver to enable PVI to appreciate a variety of artworks independently from anywhere using their own devices. As stated in the preliminary study, object-level descriptions of paintings were collected from crowd workers and used in a specific mode called Object Mode of our system. In addition to the object-level exploration, we developed two extra modes—Overview Mode and Part Mode—to help PVI understand and appreciate the painting more easily.

4.1 The Design of the System

Although our target users are PVI whose dominant feedback channel is non-visual, we designed three main modes (i.e., Overview Mode, Object Mode and Part Mode) of interaction based on Shneiderman’s Visual Information-Seeking Mantra [38]. This suggests guidelines for designing information visualization applications, for conveying visual information of artwork to PVI while reducing cognitive overload; the three steps are overview first, zoom and filter and details on demand.

4.1.1 Overview Mode

We implemented this mode as the main screen of our system to provide users with an overview of paintings before they start exploring the paintings in depth. It is designed to help users to understand which paintings are presented in the gallery or listen to basic information of each painting. This basic information was extracted from WikiArt, such as a title, artist, year, and medium as shown in Fig. 6. The user can perform either swipe gestures anywhere on a touchscreen or drag their finger to navigate items on the screen while using VoiceOver. We also informed users the ideal screen orientation (landscape vs. portrait) of each painting. Moreover, users could listen to the overall description of a painting which contains the artists’ painting style, the historical or social background when the painting was created, and widely accepted interpretation of the painting.

4.1.2 Object Mode

Users can navigate to this mode as default as shown in Fig. 7a by selecting a certain painting from Overview Mode. Object Mode provides detailed object-level descriptions which were collected from crowd workers as stated earlier from the preliminary study in Section 3. As supported from prior works [28, 19], this mode allows users to explore each object which is segmented in a polygon shape by touch while listening to object-level information in detail starting with its label followed by expression (e.g., object’s texture, shape, and status. See Fig. 3 for more examples), hue, location and size reflecting the frequency from the preliminary study. For example, if a user touches Mona Lisa’s hair on the screen, the following verbal description will be played: “Hair. Dark, long, straight, smooth, shiny, attractive, female. The color is brown, black.”. This allows users to focus on listening to the objects of interest instead of get-

Fig. 6: A screenshot example of Overview Mode displaying Mona Lisa by Leonardo da Vinci (top; A1), The Arnolfini Portrait (middle; A4) by Jan van Eyck, and Guernica by Pablo Picasso (bottom; A7).
ting information of other undesirable objects at that moment. Moreover, the system provides an attribute filtering function to allow users to filter out unwanted information related specific types of attributes: expression, hue, location and size. For instance, the description example above is the result after filtering out location and size attributes.

4.1.3 Part Mode

This mode is designed to provide details upon users’ request while or after exploring objects in Object Mode. Users can perform split-tap (i.e., tapping with a second finger while holding one finger down) anywhere on the screen to switch modes between Object and Part modes. As shown in Fig. 7, this mode highlights a set of regions and provides part-level descriptions in detail for each. These regions are suggested regions from a book called Great Paintings that includes region-specific appreciation guides of 66 of the world’s greatest paintings [20]. For instance, the following is the description will be played when a user touches the lips of Mona Lisa in this mode:

“A mysterious smile: The smile of Mona Lisa is mysterious and soft, thanks to the Sfumato that has been applied to the painting and produced dramatic impacts. The woman’s mouth is slightly raised, but it is almost impossible to read her facial expression. This smile also gives a tranquil atmosphere to the Mona Lisa.”

4.2 Implementation

Our application was originally developed as a web application so that it can be accessed from a web browser on any device with a URL link instead of downloading and installing the app. For implementation, HTML, JavaScript and CSS was used for designing the layout and styles, and D3.js was used for supporting image-related visualizations and touchscreen interactions. Moreover, Amazon EC2 with Ubuntu was used to operate LabelMe to collect data from the crowd, and Firebase was also used to deploy our web application. The application was then optimized to a VoiceOver compatible mobile app for iOS devices. It supports various web browsers including Safari and Chrome. Moreover, from the 408 valid data mentioned in Section 3.2.4 we manually checked annotations once again for the system and removed 36 duplicated annotations that represent the same objects. Thus, for each painting, 46.5 objects were annotated on average ($SD = 7.8$).

5 User Study

We conducted a user study with 9 participants with visual impairments to evaluate an effectiveness of our system for helping PVI better understand and appreciate paintings independently.

5.1 Method

We investigated the feasibility of our system with PVI by examining how well our system can support each of the four steps from Feldman Model of Criticism [11] as presented in Table 2, which is considered as an effective procedure for educating people to have better sense of criticizing and eventually appreciating artwork [10, 12].

5.1.1 Participants

Nine PVI participated in our study. As summarized in Table 3, 6 of them were male and their age is 36.2 on average ($SD = 7.7$). Seven were totally blind and the other two had light perception; their onset years were varied. All participants were familiar with screen reader for mobile touchscreens (e.g., Apple’s VoiceOver), and had prior experience of appreciating artwork in ways of visiting art exhibition. Participants were recruited through local communities for people with visual impairments. A reward worth about $30 were given to each participant as compensation.

5.1.2 Apparatus

We deployed a mobile web app version of our system described in Section 4.1 prior to running the study and accessed the link on an Apple’s iPad 5th generation with a 10” screen during the study. We asked participants to sit on a chair in front of a desk and we placed the tablet on top of the desk as shown in Fig. 8. Every session was audio-recorded for further analysis.

5.1.3 Procedure

After signing a consent form, each session began with background questionnaires followed by a semi-structured interview on their experience with art. Then participants were asked to use our system on a tablet to explore, appreciate and criticise 2 paintings using Overview Mode, Object Mode and Part Mode after a tutorial.

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7 https://d3js.org/
8 https://firebase.google.com/
Table 2: Four steps of Feldman Model of Criticism, and brief descriptions of each step.

| Steps                      | Descriptions                                                                 |
|----------------------------|------------------------------------------------------------------------------|
| Step 1. Description        | Basic information and composition of the painting                            |
| Step 2. Analysis           | Integration of elements (style, structure, and technique, etc.)              |
| Step 3. Interpretation     | Extracting meanings or messages from the painting                           |
| Step 4. Judgment           | Proposing a personal opinion based on prior steps                            |

Table 3: Participants’ demographics, including age, gender and visual acuity of their best eye.

| PID | Age | Gender | Visual Impairment (best eye) | Onset Years |
|-----|-----|--------|------------------------------|-------------|
| 1   | 48  | Male   | Totally blind                | 10          |
| 2   | 35  | Male   | Totally blind                | 2           |
| 3   | 32  | Male   | Totally blind                | 30          |
| 4   | 35  | Male   | Totally blind                | 7           |
| 5   | 30  | Male   | Light perception only        | 8           |
| 6   | 32  | Male   | Totally blind                | 18          |
| 7   | 26  | Female | Totally blind                | 3           |
| 8   | 40  | Female | Light perception only        | 10          |
| 9   | 48  | Male   | Totally blind                | 10          |

For the tutorial, we presented Overview Mode as shown in Fig. 6 and asked participants to navigate and listen to the brief information (i.e., title, artist, date, style) about the first painting on the top of the page, which was Mona Lisa by Leonardo da Vinci (A1 from Fig. 1) using VoiceOver gestures; participants were allowed to use both linear navigation with swipes and exploration by touch, however and whenever they like throughout the study. After listening to the information of Mona Lisa on their own, we presented the painting on Object Mode as shown in Fig. 7a to explore the painting and asked participants to answer what objects are depicted in the painting. Then we introduced Part Mode (Fig. 7b) to participants and have them practice switching between the two modes. We allowed them to use this mode to explore the painting as well. Before presenting the main two paintings, we explained participants about our attribute filtering function as described in Section 4.1.2, and asked whether they wish to filter any attributes or not then set filters accordingly.

We then asked participants to use our system to listen to basic information using Overview Mode and explore and appreciate two paintings using either or both Object Mode and Part Mode. The paintings we used for the study were The Arnolfini Portrait by Jan van Eyck (A4) and Guernica by Pablo Picasso (A7). While participants were appreciating paintings, they were allowed to spend as much time as they need. After the appreciation, they answered several questions which were constructed based on 4 steps of Feldman Model of Criticism as described in Table 2. Also, they were allowed to use our system freely to answer questions. In addition, we let participants listen to the overall description of the painting from Overview Mode, and provide their perceived similarities and differences between the description and what they had appreciated. Finally, participants provided their subjective opinions and personal preference for two paintings. As for the order of the presentation, participants with even PID were presented with The Arnolfini Portrait first, while others began with Guernica.

5.1.4 Data and Analysis

We collected participants’ demographic information, prior experience with artwork and subjective responses to questions during and after performing the task using AccessArt. For qualitative analysis, we removed all personally identifying information and assigned a unique identifier to each participants then coded the transcribed responses into a set of themes focusing on how our system can support each step in the Feldman model.

5.2 Findings

We summarize our findings focusing how our system, AccessArt, can be used to support each of the 4 steps in Feldman’s model of criticism to help people with visual impairments to explore and appreciate artwork independently and efficiently.

5.2.1 Supporting Description Step

All 9 participants could easily describe the basic information (i.e., title, artist, and dimensions) and the composition of paintings using all three modes of interaction. They used Overview Mode to get objective information about painting such as its title and artist.
Then they tended to use Object Mode to comprehend components of the painting first and changed the mode to Part Mode if they wished to get more detailed information.

While none of the participants knew The Arnolfini Portrait (A4) and only 3 participants (P2, P4-5) had seen Guernica (A7) before they lost their sight, most of the participants did not have any difficulty in listing objects depicted in the painting. For The Arnolfini Portrait, all participants could easily list a man, a woman, and a dog which are main subjects of the painting when they were asked to describe which objects were drawn in the painting. Also, when the same question was asked for Guernica, 2 participants (P1, P8), in addition to the ones who were aware of the painting, were able to list several objects such as broken body parts and animals based on information they obtained from Object Mode. Moreover, other participants (P1, P3, P6-7, P9) were convinced that the painting is related to a war based on the attributes from object-level descriptions such as “confused” and “shocked”, even though the word ‘war’ was not directly mentioned at all. For example, P5 responded:

“There are wailing mother and child in the painting. All of them have covered by flame in a war situation. I think a horse and a bull are emphasizing the sadness of the war.”

5.2.2 Supporting Analysis Step

Participants were able to understand the arrangement of the painting (e.g., absolute or relative location of objects in the painting) and the overall color tone after exploring paintings with Object and Part modes. While most of the participants could answer these questions, the perceived difficulty seems to be different depending on the painting. For instance, as for the arrangement of The Arnolfini Portrait, all participants could easily describe the arrangement of the painting although P3 was a bit confused as he thought that the woman would be lying on the bed. On the other hand, as for Guernica, 3 out of 9 participants (P1-3) reported that it was hard to understand the locations of objects. For instance, P2 commented that this painting is more confusing compared to other paintings because it is a cubist style of painting. P3 also responded that the painting is strange and not making sense because he thought that a body part should be below a face, but it was not in reality.

Still, the majority of the participants (P4-9) could explain the arrangement of painting quite accurately. For example, P6 described the arrangement of the scene precisely as below:

“Arrangement of the painting is chaotic and [objects are] scattered into pieces. A man lies horizontally at the bottom of the painting. A face is on the left side, and a woman embracing her child is at the above of the man overlapping with cattle. On the right side, there is a man and a woman staring the other side.”

We also asked participants to describe colors used in the paintings. For The Arnolfini Portrait, all participants assumed that the painting would be colorful, bright and warm. For Guernica, on the other hand, six participants (P1-4, P6-7, P9) assumed that the overall color of the painting would be monotonous and dark which was correlated to the color of actual painting while the remaining two participants thought that the painting would be full of intense colors as they imagined blood and fire from a war.

5.2.3 Supporting Interpretation Step

We could confirm that participants were able to guess what intention(s) the artists might have had when they were working on the paintings. We asked participants to share their own impression after appreciating each painting and their understanding of artist’s intention. For The Arnolfini Portrait, the responses were similar; participants felt wealth, warmth, and marital affection. For Guernica, all participants received strong impression from the painting. Six participants (P2-3, P5-8) described that the artist’s intention of creating the painting was to convey complete misery and despair of wars, meanwhile other three felt hope. For example, P6 mentioned that she felt hope as she noticed a light and a candle expressed in the painting.

5.2.4 Supporting Judgment Step

Finally, we asked participants what they liked or disliked about each painting if any. For The Arnolfini Portrait, most of participants favored the relationship between married couple and relaxation from wealth of the rich middle-class people (N = 6). P7 assumed that the unknown person in the mirror is probably a god, based on the fact that there were elaborate sculptures and a candle which represent religious beliefs. For Guernica, responses of participants were mostly negative when they were asked for things they like or dislike about the painting. Four participants (P1-3, P8) said that they did not have any favorite part. P2, in particular, responded that he disliked almost every part of the painting because he does not prefer dark and gloomy atmosphere of the painting. On the other hand, four participants (P5-7, P9) preferred expressions of the
artist used as a mean to convey a certain message. P9 also mentioned that he favors the message of anti-war movements that the artist tried to convey through his painting.

5.2.5 Supporting Overall Description

After completing each of the four steps per painting, we played the overall description of the painting in Overview Mode. Then we asked participants to rate their perceived similarity between their own appreciation and overall description in a 7-point scale where 7 is best and the average score was high; 6.2 for The Arnolfini Portrait (SD = 0.7) and 6.0 for Guernica (SD = 0.9). P2, whose score was 7 for Guernica, and 6 for The Arnolfini Portrait, noted that the overall description was slightly different from his own appreciation since an art appreciation is inevitably subjective while acknowledging that overall atmosphere and intention of an artist was similar. On the other hand, P8 rated 5 for Guernica because she found out from the overall description that the color of the painting was generally monotonous while she imagined a colorful image. This indicates that personal bias could be removed by listening to an objective description.

While all participants agreed that they like being able to access basic background information of paintings, several concerns were raised. Five participants (P1-2, P5-7), in particular, believed that listening to overall description can disturb them when they are trying to have their own interpretation of paintings, especially it contains subjective criticisms or interpretations. For example, P7 said:

“People who can see can make their own assessment of paintings by visually appreciating the artwork. But for me, I’ll have to accept the descriptions as it is without having a second thought even if the information is not reliable.”

5.2.6 Supporting Object and Part Modes

We asked participants to share their impression of Object Mode and Part Mode and all participants showed positive reactions unlike the overall description. In general, they reported that changing two modes whenever they want and using both modes at the same time were significantly helpful in understanding paintings. P8 reported that having both modes is way more effective because it enables her to access desirable information quickly rather than providing a long description combining two kinds of information in a single mode. Moreover, 6 participants (P1, P3-5, P7, P9) emphasized that these two modes help them to elevate their understanding of paintings. P1 reported that he felt little confusion at first because he was not used to our system, but he said that he could understand the painting far more faster than simply listening to the overall description. P4 also mentioned:

“It feels like touching the painting directly in 3D space, and communicating with the painting. I even felt that I am maneuvering the painting dynamically.”

Indeed, when we asked our participants if they prefer overall description of paintings or object-, and part-level descriptions using our system, all nine participants chose AccessArt as their preferred medium of appreciating artwork.

5.2.7 Supporting Attribute Filtering Function

After the tutorial, we asked all participants whether they want to filter out any kind of object attributes and three participants turned off size-related information (P3, P7-8), and two participants turned off location-related information (P3, P6). Then, at the very end of the study, we asked participants to provide subjective feedback on this filtering function regardless of their usage of it. Seven participants (P1, P3-4, P5-8) provided positive responses. P1 reported that it is way more effective to use the filtering function because he can access desirable attributes more quickly without listening to redundant information which he can figure out by touching the paintings on the screen. P7 also said that it would be effective because desirable attributes are varied considerably for each person with a different degree of visual impairments. For example, she emphasized that size will be undesirable for people with moderate low vision. On the other hand, P9 said that filtering function is unnecessary as he would not filter out any information and instead try to get as much information as possible.

5.2.8 Summary

The findings with qualitative assessments demonstrated that PVI can understand paintings in terms of composition of the painting and the arrangements of components in the paintings from the object-level description produced by an anonymous crowd. Moreover, participants could capture the overall mood of paintings purely based on their own interpretation that they explored using our system yet similar to overall descriptions.
6 Discussion

6.1 The Feasibility of Collecting Data of Artwork from Crowd

6.1.1 The Reliability of the Crowd Workers and the Collected Data

The HIT we designed for the preliminary study was set to automatically accept survey codes without checking for the validity of the codes themselves and the collected data. Thus, only about 60% crowd workers have completed the task as instructed. Moreover, almost one fourth of the data was invalid even for the data produced by these workers. While we were still able to get a sufficient amount of reliable data, that we assumed to be more credible compared to annotations by a couple of researchers, a special consideration is needed to collect reliable data. To be scalable, in addition to relying on collective intelligence like Wikipedia, which is in fact our ultimate goal, various methods can be used such as a special incentive system to motivate workers to show high performance [13]. Similarly, Leimeister et al. [22] also listed 4 motivations for crowd workers to provide more qualified data: learning, direct compensation, self-marketing, and social motives. We can try multiple methods to motivate workers such as informing them an objective or target users of the study. Besides, we confirmed that a rejection system that systemically excludes low quality results (e.g., accepting segmentation polygons that have at least 3 vertices) or a verification process that excludes invalid workers before they do the real task could be needed to collect qualified data as much as possible.

6.1.2 The Efficiency of the Describing Objects and Paintings

While our reward was relatively higher than 90% of the MTurk HITs [18], we could have divided into a series of simpler and constrained subtasks as suggested in a prior study [42] given that the average task completion time was over 10 minutes. For instance, we can design the task so that workers can draw a box around an object instead of drawing a polygon along with the object’s boundary. Also, we can have three tasks, one for an object segmentation, one for object description and one for scene/atmosphere description. Moreover, as for the object description, while we intentionally allowed crowd workers to freely list any keywords to identify the types of attributes they crowd workers tend to provide, it would be more efficient to collect keywords for certain types of attributes. For example, we can prioritize types of attributes based on the needs of people with visual impairments who wish to learn about artwork; collecting expression-, and color-related information rather than keywords related to location and size. In addition, as color, location and size of an object can be computed automatically once the boundary of an object is specified, focusing on other general expressions that visually describes each object such as texture, shape and status while considering the genre of the paintings where one type of attribution is more informative than the others.

Meanwhile, as for the description of the entire painting, the instruction needs to be more specific so that the data collected is more useful to people with visual impairments. It would be interesting to investigate if workers are more likely to provide informative annotations if they are informed that their data will be used for people with visual impairments for appreciating artwork.

6.2 The Feasibility of Supporting the Appreciations of Artwork for PVI

6.2.1 Understanding Artwork from Object-level Descriptions

There is no right answer for artwork appreciation and thus there is no objective measurement of how successful one has appreciated artwork. Thus, we asked questions based on 4 steps of Feldman Model of Criticism focusing not on how closely each participant has understood general descriptions written by professional art critics, but on how participants were able to construct their own interpretation and judgment.

In this regard, the participants from our study were able to understand the objects drawn in a painting, their arrangements as well as their attributes sufficiently well to capture the overall mood of a painting just from the object-level description. For instance, although the level of understanding can vary depending on the genre of the painting, even for Guernica, which is a cubist style painting, participants could describe arrangements using our system. Moreover, they perceived that their impressions and interpretations were very similar compare to the overall description of a painting written by an expert. This suggests that our system can help people with visual impairments can access and assess paintings independently and creatively without passively relying on others’ opinions. Still, we recommend providing the overall description in addition to object-level
descriptions of artwork for the ones who wish to get more information including other people’s interpretations. As a result, although verifying an ability of people to understand the artwork is difficult, we suggested the method to judge the ability of PVI to independently interpret or even criticize the paintings as an extension of prior works [1, 33].

6.2.2 The Effectiveness of Conveying Visual Information with Our Design

As described in Section 4.1, we applied Shneiderman’s Visual Information-Seeking Mantra when designing three main modes of interaction. Participants valued an ability to listen to the brief description of an object starting with its label followed by its attributes by scanning the painting on the screen as an overview in Object Mode and switch the interaction mode to Part Mode to get additional and detailed information on demand. In addition, the design also meets focus+context [1] as users can understand the components and the arrangements of objects in the depicted scene of the painting. Moreover, participants showed positive reaction towards attribute filtering function as it allows them to focus on information they wish to get and filter out the rest. It would be interesting to investigate how the same approach can be applied for other types of artwork such as sculptures or in 3D space for describing the visual information about surrounding elements.

6.2.3 Applying a Vision-Based Method to Non-Visual Perception

According to Arnheim [3], despite absence of vision, sightless people can access and perceive artwork as sighted people with the help of haptic exploration, kinesthetic perception, and auditory information as an alternative way of vision. He claimed that In this regards, although Shneiderman’s Visual Information-Seeking Mantra is designed to convey visual information for sighted people, we believe that this approach could also be effective for conveying the visual information of artwork in a non-visual way (i.e., verbally, kinesthetically, and haptically).

Through the user study, participants could understand artworks as much as sighted people using our system. It insists that the vision-based method could also be applied for PVI in non-visual way to understand artwork.

6.3 Limitations and Future Work

Although the scope of study is to examine the feasibility of our approach for supporting people with visual impairments to appreciate artwork based on object-level description collected by the crowd, ours have limitations. First, as a feasibility study, a further investigation is needed for thorough evaluation of the effectiveness our system. For instance, we did not control crowd workers prior knowledge of the since eight paintings we have used for the study. Thus, the segmentation results may differ. While assumed that no workers have expertise in artwork, providing detailed instruction (i.e., “Please list at least three keywords that best describe the object(location, color, size, shape, texture, etc.)”), one’s knowledge of specific artwork may have influenced the performance. Furthermore, we provided part-level descriptions which are from the book in Part Mode which lacks scalability of our system. As a future work, we should devise a more scalable method such as collecting professional part-level descriptions from art experts. We also plan to open our app to the public to examine if and how our system can be scaled up and maintained in the wild. Moreover, we wish to evaluate our system as an educational tool for anyone who are interested in the arts.

7 Conclusion

We investigated the feasibility of collecting visual descriptions of components in artwork from an anonymous crowd based on annotation data of 8 paintings produced by Amazon Mechanical Turk workers. In addition, we proposed AccessArt, a web application system designed to enable people with visual impairments to appreciate various artwork online by listening to object-level descriptions drawn in a selected painting on their personal touchscreen-based devices then conducted a user study with 9 participants with visual impairments and collected their subjective feedback during and after using the proposed system to assess the potential in terms of how well our system could support each of the four steps in Feldman Model of Criticism. Our findings suggest annotations produced by non-expert crowd workers is capable of generating informative labels and attributes to help people with visual impairments to interpret and judge paintings independently based on their own perspectives rather than passively accepting the information written by professionals. As a future work, we plan to expand this work on a large-scale and make the system public to improve the accessibility of a greater number of paintings for people with visual im-
Acknowledgements This work was supported by the Ewha Womans University Research Grant of 2018. Also, the research was supported by the Science Technology and Humanity Converging Research Program of National Research Foundation of Korea (2018M3C1B6061353).

Compliance with ethical standards This study was approved in advance by a university Institutional Review Board (IRB) with the approval ID of ewha-201904-0001-01.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Fig. 7: Screenshot examples of (a) Object Mode and (b) Part Mode. Objects and part segments are shown in colored borderlines. In both modes, users can listen to verbal descriptions of each region upon touch.
Fig. 8: A participant (P9) exploring objects in Mona Lisa using our application in *Object Mode*.