identity.space

Creating shared generative audio-visual art pieces based on NFC data in ID cards

Project Report

DT2140-HT20 Multimodal Interaction and Interfaces

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Abstract

Building on works that use biometric data to create multimodal art pieces, this project utilises the unique identification numbers in personal identification (ID) cards to create a shared audio-visual representation of a connected group's background and composition. The four-byte identifier of the near-field communication (NFC) tag in each ID card is mapped to both visual (e.g. colour, position, size, and animation of displayed elements) and audio parameters (e.g. partials of an oscillator's harmonic series; note, octave, and timing of a triggered sound) of the resulting art piece. In addition to the tangible input of the personal ID card, participants can use their smartphone's touch screen to trigger the attack and release of the associated sound for their connected personal ID card. An explorative evaluation of the interaction shows that, while the art piece is considered attractive by the participants, it largely fails to elicit a strong reaction related to the concept of identity. Future works should focus on enhancing users' perceived control of their contribution to the resulting art piece as well as the connection to participants' personal data and characteristics, for example by making use of additional sensors of the connected smartphone or by employing more transparent parameter mapping.

Introduction

In recent years, digital data stored on personal ID cards have become increasingly accessible to application developers with countries like Germany offering registered service providers access to, for example, a person's name and address using the ID cards' electronic identification (eID) feature [1]. This has enabled new and more streamlined services, especially in the public sector. By reading data stored on the NFC chip inside a personal ID card, citizens of the European Union can, for example, identify themselves to public services across member states and access these services independent of their country of origin, significantly reducing administrative effort [2]. With the introduction of the API *Core NFC* to Apple's mobile operating system *iOS* in 2017 [3] and its extensive update in 2019 [4], these services have gained additional traction as applications that previously worked only on the *Android* operating system could now be used by *iOS* users as well. Yet, the overall number of eID-enabled services remains rather low [5]. Independent of, but concurrent with this development, debate about political polarisation, especially in regard to the role of digital services like social media, has become more prevalent across countries not only in Western societies [6]. Our project aims at using generative art as an outlet to promote and illustrate the capabilities of eID-enabled cards while simultaneously showing how diversity of backgrounds can make groups and society as a whole more interesting and attractive for its members by leveraging the digital data stored in personal ID cards.

To achieve this goal, the unique identifiers of the NFC tags inside personal ID cards are used as seed for generative visual art and sound. This way, each ID card contributes to a unique multimodal art piece representing a group's identity. The aim is to create an interesting personal and communal experience where individuals can gain a personal connection to generative visuals and sound as well as explore the technical possibilities of their ID cards. Moreover, we aspire to create a sense of community as participants' diverse identities create a larger and more complex piece of art than each individual could.

Related Work

This project builds upon two main lines of research: publications on generative visuals and sound, especially in regards to generative art, and research on representations of personal data, especially in regards to unique personal features like biometric data.

Generative visuals when presented in a real-time and interactive format require well-written algorithms for ideal performance. A popular technique is a fluid simulation that allows aesthetic exploration with adoption at ease [7]. To give an example of one such implementation that uses vector visualization techniques specifically designed for media arts you can view visual results of the Fluid Automata system [7] in the figure below.

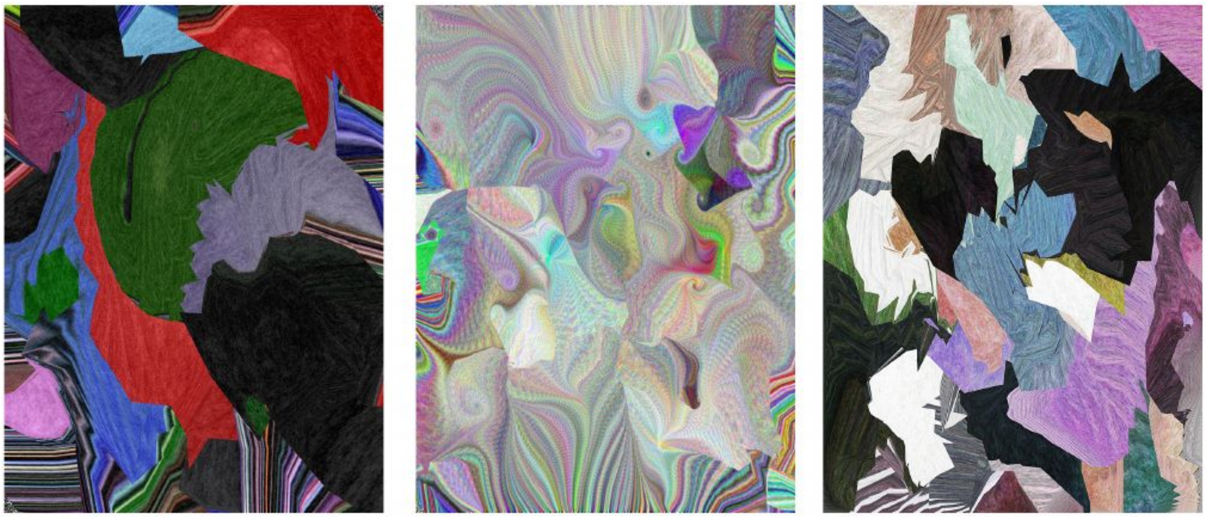

Figure 1. *Using the Fluid Automata system with customization on a few parameters to create different visual effects [7].*

These methods work similarly by recording pixel state along with the surrounding ones, interactions then affect the system by a sense of energy input [7]. After the effect is applied and elements are combined, the influence of the input ends [7]. Through this iterative process, it creates a unique result each time with different interactions and various parameters mapping. One additional common characteristic among many fluid simulation techniques is their accessibility on various platforms, since many of them are open-source or available for multimedia frameworks like OpenFrameworks and Processing [7]. Moreover, fluid simulation techniques like the Fluid Automata system can be adapted to control audio, making it useful for audio-visual works [7]. For our project, we were inspired by such generative visuals that could be connected to sounds and, depending on the input or seed, could result in a repeatable but unique art piece to build our own representation using a similar, but simplified approach. Especially the common occurrence of the Processing framework proved a valuable insight for our technical implementation.

Another line of research that provided relevant insights to our project is work on the use of biometric data as input for audio-visual art pieces. In projects like Digiti Sonus [8], Eyes [9], or The Roads of Your Veins [10], biometrics such as fingerprints, iris scans, or vein profiles are captured and processed to map the extracted features to parameters of visualization or sonification algorithms (see Figure 2).

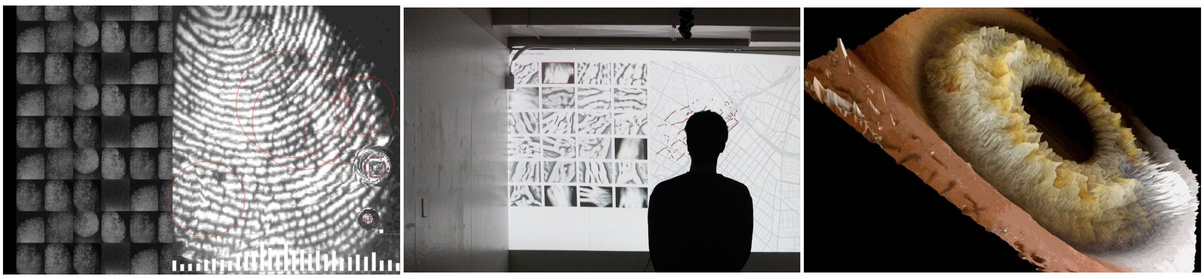

Figure 2. *Visualizations of biometric data in the Digiti Sonus [8] (left), The Roads of Your Veins [10] (middle), and Eyes [9] (right) projects.*

As some of these projects use similar open-source visualization and sonification libraries to those used for generative art and document their parameter mapping as well, we were able to study their strategies as guidance for our own mapping approaches. In the case of Digiti Sonus [8], the paper also notes some additional interaction techniques that were implemented (e.g. gesture input to navigate the fingerprint gallery) and how those contribute to the overall participant experience. Our project was inspired by this to consider additional interaction modalities and how they could be used to enhance the experience of participants in our study.

Design

Building on the insights from our literature study, the result of our project is an interactive audio-visual art piece called *identity.space* that is based on the visualisation and sonification of personal ID cards' unique NFC identifiers. In an installation setting, a commonly visible and audible display and speaker setup would be used to output the audio-visual art piece representing all connected personal ID cards by opening the associated web client (see Figure 4). For most users, the display would show multiple colourful spinning arcs which "light up" from time to time while seemingly emitting a sound or note signaling that other users are already connected to the *identity.space*. A new user or participant can open the mobile client on their smartphone (see Figure 3) and tap their personal ID card against the device which, in turn, reads the data stored in the card's NFC chip including its four-byte identifier[1].

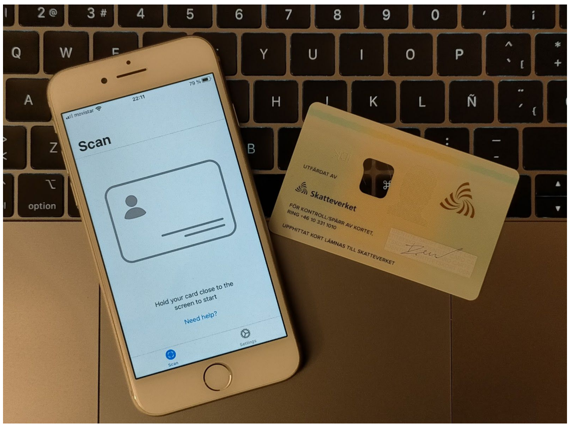

Figure 3. *Mobile client on a smartphone (left) and example personal ID (right). A blank NFC card was prepared to resemble a valid personal ID card for evaluation.*

The data is then sent to a web server and client resulting in the rendering of an additional arc while the mobile client displays a button labelled "Hold to activate your ring". Pressing down the button results in a sudden increase in brightness and saturation of the newly added arc (the previously mentioned "lighting up" effect) and the triggering of a note from a synthesizer. Releasing the button ends both effects as the arc reassumes its original brightness and saturation and the note is released. After a period of inactivity (i.e. thirty seconds without a button press on the mobile client), the arc starts to "light up" and emit its sound in a fixed interval between three and ten seconds as determined by the NFC identifier. Depending on the number of connected personal ID cards, the web client can display a rather calm image with only occasional sounds or a busy array of rings with frequent increases of brightness and accompanying sounds in a composition bearing some resemblance to an abstract rendition of a fingerprint or an iris (see Figure 4). In contrast to the biometric

[1] As will be discussed in further detail in the Implementation and Discussion sections of this report, this step is only simulated in our current implementation.

art discussed in the Related Works section, this visual is used here to represent not an individual's but a group's unique features.

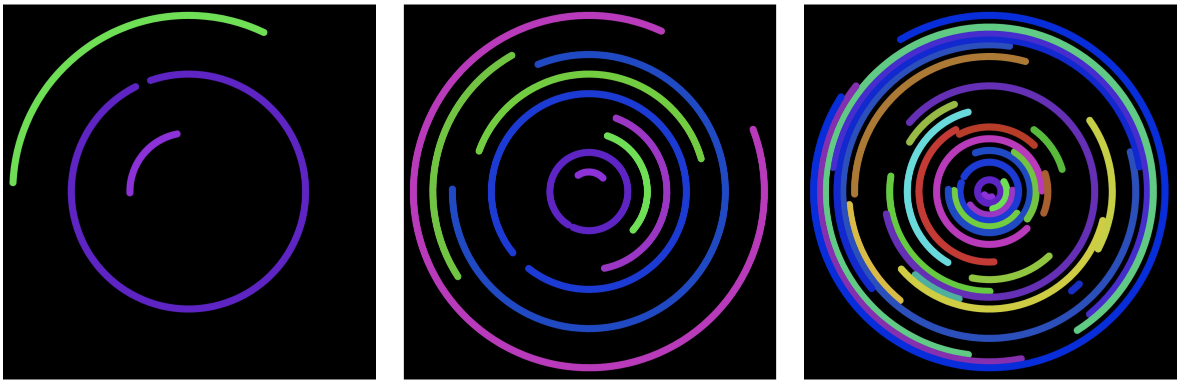

Figure 4. *Visual output for three (left), nine (middle), and thirty (right) connected personal ID cards. Each spinning arc represents one ID card and is based in its visual properties and animation on each card's unique NFC identifier. Card holders can interact with the art piece using the mobile application where they can trigger a temporary increase of their corresponding arc's brightness and a simultaneous predetermined sound.*

Modalities

There are three modalities involved in the project: tangible, visual, and auditory. With the ID card as the source of information about one's identity, bringing the card closer to a phone is an intuitive way of interacting through tangible input.

Visual and auditory output modalities were used in the artwork. As the main idea was to introduce a form of generative art, choosing modalities with high symbolic properties was suitable to symbolise an artistic representation of an ID card and combinations of multiple ID cards. Since the human brain handles visual and auditory information partly independently, humans can interpret simultaneous visual and auditory information [15] making the use of synchronised audio-visual information a suitable choice for this symbolic representation.

Using multimodal art in the form of both visuals and audio makes the experience more immersive, which relates to the complementarity of the two modalities, as they represent different information. In addition, the complementarity allows us to significantly modify the whole artwork by altering only one of the modalities, e.g. using sawtooth or sine oscillator for the sound but keeping the same visuals. Thereby, a change in one modality affects the whole artwork creating a different atmosphere. This links to the idea of multimodal interfaces having high expressive power, which is important in the case of creating art [16]. Flexibility is also taken into account in the choice of the modalities as using visual and auditory output allows people with temporary or even permanent hearing or sight problems to experience the resulting art piece at least partly and still participate in the experience.

Furthermore, visual and auditory modalities appeared to be suitable as the goal was to represent a community. Visual and auditory output modalities provide naturality in terms of communication with others, as humans often receive information from other humans through their auditory and visual senses [20]. By also adding haptic output, which is a third way of communication that is natural for humans, we could further increase naturality while simultaneously improving flexibility, by providing even more ways of experiencing the interaction and the artwork.

In addition to haptics as an output modality, motion was discussed as an additional input modality, that is, using motion sensors to let participants interact with the artwork by moving their device. However, they were decided not to be included in the project as they would have required additional time to implement and thereby exceeded the course schedule. Moreover, haptic output in particular, even if implemented well, might have been very difficult to discern in the case of multiple IDs. While especially visual information has high temporal resolution, overlaying haptic output might have caused issues in understanding and even frustration for participants. Therefore, visual and auditory output modalities were chosen over the other options because they were considered as the most essential for representing the kind of generative artwork desired.

The chosen modalities do not have many disadvantages in the context of this project. It can be mentioned that using varying and generative sounds requires a careful design, that creates a combination of sounds that is pleasant to listen to, and contributes positively to the whole experience. Therefore psychoacoustics, i.e. the psychology behind sound perception that includes the physical properties of sound as well as emotional and cultural connections to sound, have to be considered in the design [19].

Implementation

The project was developed through three phases. Firstly, a mobile application was created that utilises the NFC reader on a mobile phone to read an NFC card and validate the received data. Secondly, a web server was developed to facilitate communication between the mobile client and the web client. Lastly, the web client served as the main stage for multimodal interaction, processing data from the web server to render an audio-visual experience.

We used a cross-platform Angular framework called *Ionic* [11] to create a mobile application that reads an identity card's identifier via NFC and sends it to a web server using web sockets. The application is web-based, though we created a native iOS 14 compilation using *Capacitor* [18], which allowed us to access some additional phone components, such as the NFC reader. The application has a *settings* tab where the user can specify the web server address (that is, IP address and port) and test the connection endpoints, if needed. These settings are then saved and used to send the information retrieved from the NFC card. Once a card is read, the application will show a window with useful information about the connection. If the connection is successful, it will display a button to interact in real time with the web server via web sockets, using socket.io for Angular. Some visuals, including an ID card representation and a set of icons, have been specifically created for the app using the user interface design software *Sketch*.

Due to the limitations set by the *iOS* mobile operating system, we were unable to access the necessary system resources to read an NFC card's information without a paid developer license. Therefore, we simulated this part of the desired experience by sending a randomly generated four-byte NFC ID of realistic format to the web server instead.

The web server handles all received NFC identifiers, acknowledges their reception to the mobile client and forwards them to a web client responsible for the audio-visual output. All communication is implemented using web sockets as provided by the *JavaScript* library *Socket.io* [12]. The web server further handles the removal of NFC identifiers on the loss of connection and requests to toggle the current state of an NFC identifier's audio-visual representation.

Finally, the web client receives data about all currently connected NFC tags as well as their current state, extracting the necessary parameters from each NFC identifier by splitting and interpreting the four-byte number sent via a hexadecimal string. Then, it renders an audio-visual representation using said parameters as input for the methods provided by the visualisation library *p5.js* [13] and the sonification library *Tone.js* [14], both implemented in *JavaScript*. *p5.js* in particular is the *JavaScript* implementation of the Processing library discussed in the Related Work section.

Each NFC ID is visually represented by a spinning arc and auditorily represented by a custom synthesizer playing a predetermined note. More specifically, the four integers extracted from the NFC identifier (each ranging from 0 to 255) are mapped to determine visually: (V1) the length of the arc, (V2) initial start angle, (V3) colour (i.e. hue, saturation, and brightness), (V4) the speed of the spinning animation, and (V5) the interval of the lighting up animation when a user has not given input for in a specified period of time (see Figure 5). Auditorily, the identifier links to (A1) the partials of an oscillator's harmonic series and (A2) the note and (A3) octave of the sound that is triggered every time the arc lights up (see Figure 6). In the following, the parameters are explained in more detail.

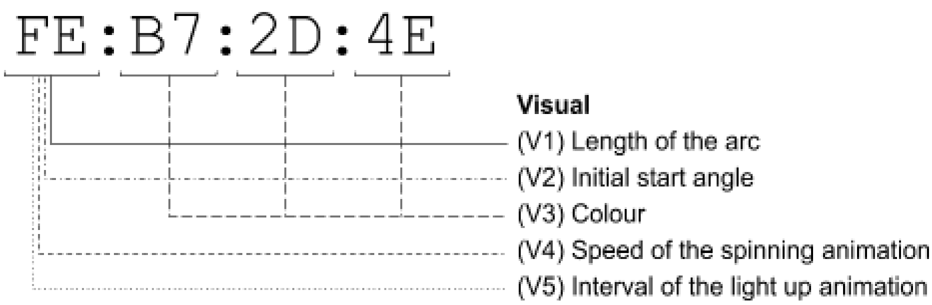

Figure 5. *Parameter mapping for the visual features of the implementation. A four-byte NFC ID is divided into four integers ranging from 0 to 255 and transformed to determine various characteristics of the resulting visual representation.*

(V1) Length of the arc: The first parameter (i.e. the first integer of the 4-four byte NFC identifier ranging from 0 to 255) was transformed to a float ranging from 0.05π to 2π using a linear function. The minimum was chosen, so that even a very small integer as the first parameter would result in a visible arc. The maximum was chosen as it represents a full circle.

(V2) Initial start angle: Similar to (V1), the first parameter was again linearly transformed to a float between -2π and 2π, so that the arc representing an NFC identifier could assume any angle of a circle.

(V3) Colour: For the third visual characteristic, the colour model hue-saturation-brightness (HSB) was chosen to achieve diversity of hues while still retaining some commonality and harmony between colours. The second integer of the NFC identifier is linearly transformed to a value between 0 and 360 and mapped so that it could assume any hue of the model. The third integer is linearly transformed to a value between 80 and 95 and mapped to saturation, and the fourth integer is linearly transformed to a value between 70 and 90 and mapped to brightness. Through these specifications, the colours will appear vibrant and varied but still harmonic when viewed together as in the case of multiple connected IDs. The maxima for saturation and brightness were chosen to leave some room for an increase during the "lighting up" animation where both are set to 100 and slowly decreased over the course of fifteen frames.

(V4) Speed of the spinning animation: To achieve a dynamic image, even in case of inactivity by the participants, each arc was animated to be spinning with a speed determined by the first byte of the corresponding ID card's NFC identifier. It was linearly transformed to a float between -1 and 1 indicating direction and speed through sign and value.

(V5) Interval of the lighting up animation: The first byte of the NFC identifier was additionally linearly mapped to an integer ranging from 90 to 300 and used to specify the interval in which the "lighting up" animation (i.e. a sudden increase of saturation and brightness to a value of 100, before they are linearly decreased to their initial value over the duration of fifteen frames) occurs, if the participant did not further interact with the art piece using the mobile client (i.e. 30 seconds of inactivity after the last change in state). As the frame rate for the visualisation through the web client was set to 30 frames per second, this interval would result in a "lighting up" every three to ten seconds. Alternatively to this inactivity period, users of the mobile application can control the lighting up of the arc as well as the firing and release of the accompanying sound by pressing, holding, and releasing the provided button.

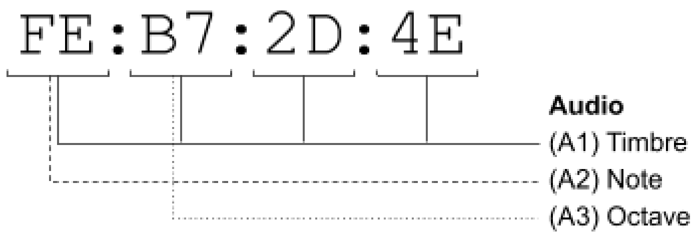

Figure 6. *Parameter mapping for the auditory features of the implementation.*

(A1) Timbre: To achieve a different quality of sound even if the parameter mapping had determined the same tone, additive synthesis was used to create a unique synthesizer for each ID card connected to the web server. More specifically, four partials of an oscillator's harmonic series were amplified or dampened as determined by the linearly transformed four bytes of the NFC identifier with each parameter ranging from 0.0 to 1.0. The envelope of the sound was kept the same for all ID cards to retain some consistency in sound across IDs with a specific focus on a long release with exponential decay to achieve some sonically pleasant and harmonic overlapping of sounds. Alternatively to partials, the envelope's parameters attack, decay, sustain, and release could have been used to map the NFC identifier to a more unique and distinct sound.

(A2) Note: The first byte of the NFC identifier was mapped to a note of the modern C Dorian scale to achieve a somewhat melancholic sound with some harmonic friction that would still result in a pleasant sound when two or more notes would overlap.

(A3) Octave: To achieve some additional variety without resulting in barely audible or unpleasantly high tones, the second byte of the NFC identifier was linearly mapped to an integer ranging from two to six and used as octave for the note to be played, resulting in a tonal range from C2 to Bb6.

All libraries used for the project software are open source and can be found in the references. The software architecture and data flow are illustrated in Figure 7.

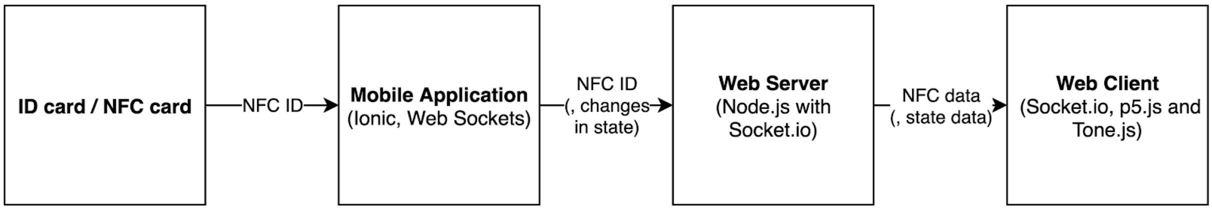

Figure 7. *Architecture and data flow for the project software.*

Evaluation

We chose a mixed-methods approach to investigate the emotional experience when interacting with the art piece. More specifically, a semi-structured interview was used alongside a standardised scale to measure emotional response to a stimulus. During the experiment, participants were shortly introduced to the overall idea and background of the project, before they were led through the experience of connecting an additional personal ID card to the shared *identity.space* (i.e. the web server and client that already had four personal ID cards connected). Afterwards, they were asked to describe their overall emotional experience as well as to explain what they felt the author of the piece wanted to express. Additionally, they were asked to rate their experience using the Self-Assessment Manikin (SAM) developed by Bradley and Lang along the measures of valence, arousal, and dominance on a nine-point scale [17] (see Figure 8).

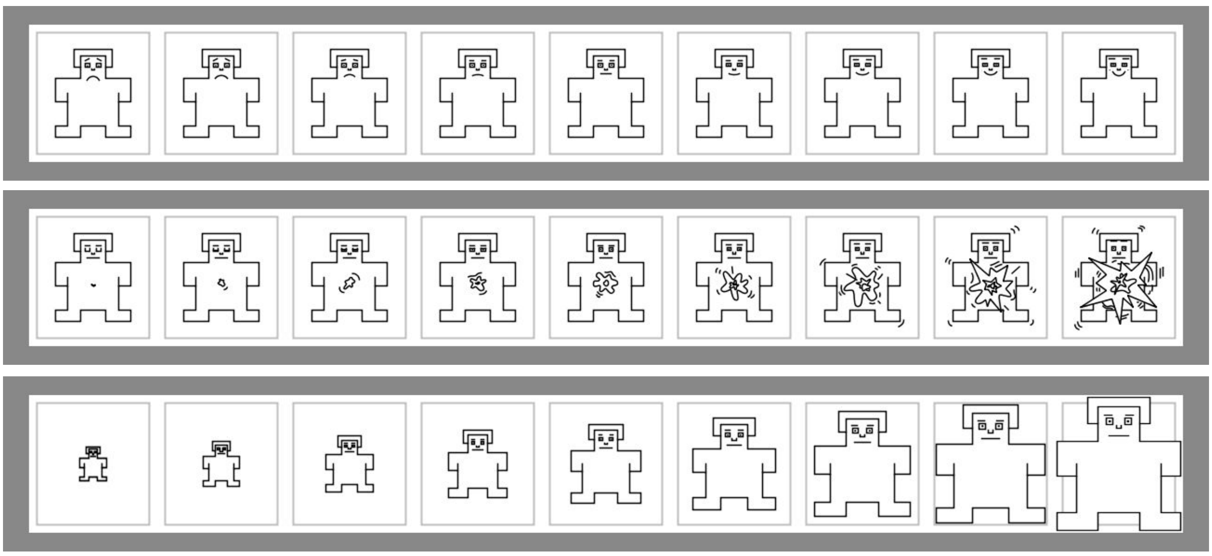

Figure 8. *Self-Assessment Manikin (SAM) scale developed by Bradley and Lang [17] in the nine-point variant for the measures valence (top), arousal (middle), and dominance (bottom).*

The evaluation involved 6 female participants between the ages of 24 and 38. The participants originated from different countries in Europe and Asia, namely Germany, Taiwan, Spain and France. For each experiment, a smartphone running the mobile client and a laptop running the web server and client were used in conjunction with a sample NFC card prepared to resemble a personal ID card (see Figure 3). The results of the evaluation are displayed in long form in Appendix A and summarised in Appendix B.

Most of the participants remarked how the experience may improve as more users participate, and at the same time how calm and interesting it is. This is supported by the results of the SAM displayed in Figure 9. The emotional experience was considered positive with low arousal indicating a calming presence and with some lack of control as indicated by the low score in dominance. There is also a common point resulting from the interviews in how the audio-visuals can represent a community and its connections within.

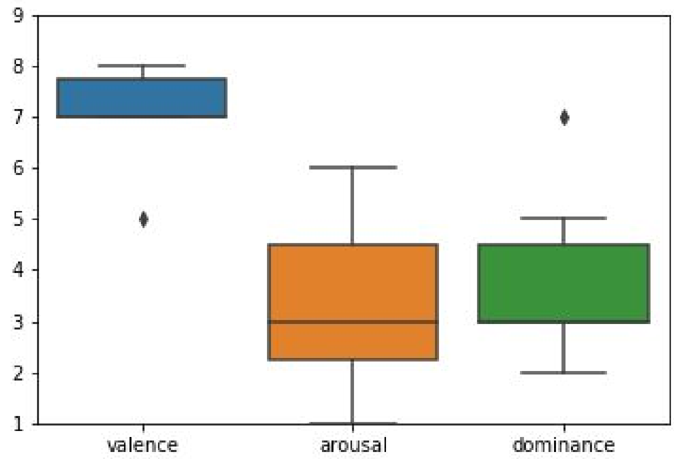

Figure 9. *Results of the evaluation using the Self-Assessment Manikin (SAM) in its nine-point variant (n = 6)*

Discussion

The project differs from the aforementioned previous work as the community perspective is strongly included in the art work. It draws and expands upon the previous work concerning biometric art by considering personally unique but non biometric data. The visual output that is created from the NFC IDs, is aimed to resemble an “artificial fingerprint” of a community emphasising this connection.

One of the strengths of the project is that the idea is accessible and inclusive. It allows everyone with an ID card to experience a personal piece of digital art and experiment with the technical features of their ID cards. Three different modalities are applied in the project and the flexibility aspect of a multimodal interactive system is considered in the output modalities. The project also has various possibilities to be developed further, e.g. by including different ways of interaction, personalised features in the artwork, and using the artworks in common spaces, such as museums. The results from the evaluation showed that the project succeeded in creating an attractive and interesting art experience.

One weakness of the project was that adding more ways for interaction could have positively affected the feeling of connection and control that the user has with the artwork, but we had to prioritise the most important features as there was a limited timeframe. Also, the initial plan changed slightly as the data in the NFC chips could not be read. However, the problem was successfully solved by generating realistic NFC IDs inside the mobile client and preparing it to function using real IDs as well.

In its current implementation, the simulated reading of an ID card allows participants to refresh the arcs until a preferable one is found. However, if the original idea of scanning a real card was used, the artwork created from one's ID would always remain the same. This was considered as a weakness by the authors, but it was also discussed that if the connection of the artpiece and identity is explained, it can still be enough for the user to personally connect with the artpiece.

The evaluation results also showed that some participants felt a lack of connection with the arcs, and did not know which one represented their ID when combined with other IDs. On the other hand, two out of six participants related the visuals to the image of a fingerprint, which empowers the notion of shared and unique identity that this project represents. We can also point out the resemblances one participant found to an image of the universe or planets, relating it with a calm experience. This notion could be explained by the visuals of spinning rings as well as by the musical scale that has been chosen for the auditory parameter mapping, found often in jazz, which may strengthen this feeling. We additionally noted that some participants tried to find a *practical usage* or a "takeaway" for a community in this project. This might relate to the rather low dominance scores measured through the SAM.

Future Work

One of the weaknesses that became evident in the evaluation was that the participants did not feel a strong connection with the artwork. We suggest solving this weakness by, for example, adding a screen that will appear after scanning the ID card and before starting the dynamic artwork that would show how the features of the arc relate to the participant's ID and explain why those features were used. We believe that this would support the users in, firstly, knowing which one of the arcs is theirs, and secondly, understanding why, e.g., the color and length were chosen, and by knowing that, get a stronger connection with the artwork.

Another possibility is to enhance the connection using alternative personal data like one's family and given name, date and place of birth, or address and postal code as parameters that can be obtained from the ID cards by scanning them. This mapping could be more easily understandable for the users compared to the ID number that is used in this version.

Finally, the connection could be strengthened by enabling further interaction using additional sensors. The accelerometer in a smartphone could, for example, be used to control visual (e.g. brightness) and sonic features (e.g. volume) of the corresponding arc to enhance the connection between the user and the art piece.

While our project has laid the groundwork for such further exploration, additional studies can provide valuable insights into the relationship between multimodal interaction, generative art, and communal identity.

Conclusion

The goal of this project was to explore how multimodal generative art could be used to illustrate the beauty of diversity within a group or a community as well to have participants experience the technical capabilities of their personal ID cards. We, therefore, implemented a shared audio-visual art piece based around NFC data in personal ID cards that allows every participant to experience a personal and shared piece of art. As our evaluation shows, we achieved this goal while opening discussion to various additional exploration of the underlying concept. While our implementation was considered attractive by the participants, it failed to elicit strong reactions related to the concept of identity. Additional studies should be conducted to further understand and enhance participants' connection to the resulting art piece and to the sense of communal identity.

Supervision Intake

Our supervisor, Roberto Bresin, approved the initial project idea, suggested various directions that could be taken from the initial idea, and referred to existing interactive artwork that we could look into. He reminded us of aspects that have to be taken into account when designing sound effects and recommended evaluating the experiences of the participants using a standardised scale, which we decided to do with the SAM evaluation method.

Link to the Project on Vimeo

https://vimeo.com/501503049

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Appendix

Appendix A: Results of the Semi-Structured Interview During the Evaluation

(1) France F 24 SAM-[5,3,3]
She pointed out that the experience was not so interesting when using it individually, but that it was interesting to see one's identity reflected "in a beautiful way." She felt that it looked like the universe or like zooming in on a planet. Even like a fingerprint made from the collective identities.

(2) Germany F 25 SAM-[8, 3, 3]
She found the overall experience quite fascinating and beautiful to look at, even almost hypnotising at times. After a first fun and excited period of playing around and testing the interactive components of the prototype, she tried to synchronise her activity with those of other arcs to create harmonies and dissonance. After around thirty seconds of quietly interacting with the prototype, I asked her about the experience and what we wanted to express and she said that the idea might have been to show the diversity and connectedness of a community or group. As a side note, it should be mentioned that she connected and disconnected her "ID card" from the service until it had generated a "colour she liked".

(3) Spain F 25 SAM-[7,2,2]
She described the experience as calm, colorful and interesting. She noted that it could be useful for her meditations. Additionally, she felt it expressed the notion of belonging to something bigger.

(4) Taiwan F 24 SAM-[7, 5, 3]
She thought the experience to be interesting but wondered what would be the takeaway for the community and the connection with the person. However, she found the project expressing something new through the collection of identities. Also, she noticed a two times transformation of identity, from the identification card that turns a person into numbers or a symbol to the project that takes the data into visuals and sounds.

(5) Taiwan F 28 SAM-[8, 6, 7]
Overall, she felt new and fresh from the experience. Also, she was curious about the outputs, wondering whether she can get the information of others or make communication. She perceived the project as a tool to let people know each other faster and thought the visuals represent the fingerprint as the identification of the community.

(6) Taiwan F 38 SAM-[7, 1, 5]
She described the experience as peaceful and spiritual. Also, she observed the project expresses a sense of identity in a community but unsure about the connection between.

Appendix B: Evaluation Results of the Self-Assessment Manikin (SAM) and Semi-Structured Interview

Country	Gender	Age	Valence	Arousal	Dominance	Emotional response	Suspected meaning
France	Female	24	5	3	3	beautiful, a little uninteresting alone, reminding of planets or a fingerprint	fingerprint made from collective identities
Germany	Female	25	8	3	3	fascinating, beautiful, almost hypnotising	diversity and connectedness of a community or group
Spain	Female	25	7	2	2	calm, colourful, interesting, meditative	belonging to something bigger
Taiwan	Female	24	7	5	3	new, interesting, slightly confusing	collection of identities, two-step transformation of identity
Taiwan	Female	28	8	6	7	new, fresh, curious	let people know each other faster, fingerprint of a community
Taiwan	Female	38	7	1	5	peaceful, spiritual, unsure about meaning	sense of identity in a community

Valence, arousal, and dominance were collected using the Self-Assessment Manikin (SAM) developed by Bradley and Lang [17] in its nine-point variant while emotional response and suspected meaning were collected using a semi-structured interview.