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Biometric Data Art: Personalized Narratives and Multimodal Interaction

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Biometric Data Art: Personalized Narratives and Multimodal Interaction

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy
in Media Arts and Technology

by

Yoon Chung Han

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December 2016

The dissertation of Yoon Chung Han is approved.

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September 2016

Biometric Data Art: Personalized Narratives and Multimodal Interaction

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I thank all my families and friends in both USA and S. Korea, who have been always supportive for my long journey toward PhD. I send my warm hearts to my parents for their unconditional love, encouragement, and great support. I thank to my aunts and uncles for their infinite support, encouragement and warm hearts. I devote my dissertation to my grandmother, Dong Won Lee who is always in my heart.

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I acknowledge financial support from the Media Arts and Technology graduate program, and DaVinci Media Art Program at the GeumCheon Art Space, Seoul Art Space.

Curriculum Vitae

Yoon Chung Han

EDUCATION

09.2011-12.2016 **PhD in Media Arts and Technology**
University of California, Santa Barbara | Current GPA: 3.9/4.3
Dissertation "Biometric Data Art: Personalized Narratives and Multimodal Interaction"
- Selected Course works: HCI (Human Computer Interaction), Algorithmic Data Visualization, Digital Media Technology and Engineering, Programming with Media Data
- Advisor: Prof. Curtis Roads

09.2008-08.2010 **MFA in Design | Media Arts**
University of California, Los Angeles| GPA: 3.8/4.3
- Selected Course works: Interactive Media Art and Design, Physical Computing, Network Media, User Experience Design
- Advisor: Prof. Casey Reas

03.2006-08.2008 **MFA in Design (Interaction Design)**
Seoul National University, Department of Craft & Design | GPA: 3.9/4.3
- Selected Course works: HCI (Human Computer Interaction), Interactive Musical Interface design, User Experience Design, Interactive Media Arts
- Advisor: Prof. Suzung Kim

03.2002-02.2006 **BFA in Graphic Design**
Seoul National University, Department of Craft & Design | GPA: 3.4/4.3
- Concentration in Graphic Design, Web Design, Visual Communication Design

WORK EXPERIENCE

08.2015-Current **California State University, Fullerton** (Fullerton, CA)
Assistant Professor in the Department of Visual Arts
- Teach "Computer Assisted Graphics" (UI/UX Design for Web and Mobile)
- Teach "Special Studies in Graphic Design" (Infographics and Data Visualization)

01.2015-05.2015 **University of San Francisco** (San Francisco, CA)
Adjunct Faculty
- Teach “Interaction Design” (Interaction Design for Web and Game in Processing)

09.2014-05.2015 **Academy of Art University** (San Francisco, CA)
Adjunct Faculty
- Teach “Introduction to Computer Programming” to Undergraduate Students in Liberal arts and Design department
- Teach Processing, Java Programming, Basic Mathematics and quantitative analysis

03.2014-07.2014 **SENSEable City Lab, MIT** (Boston, MA)
Data Visualization Specialist and Visiting PhD Student
- Research and Design Interactive Data Visualization related to diverse urban data
- Develop Data Visualization and Web Design for the project “Art Traffic at the Louvre”

09.2012-03.2014 **Experimental Visualization Lab, UCSB**(Santa Barbara, CA)
Graduate Student Researcher and Teaching Assistant
- Researched and Designed various new and simple Data Visualization methods and
interface design using Seattle Public Library Data
- Designed a new Interactive 2D&3D Data Visualization and Sonification in AlloSphere
- Taught Data Visualization, Processing + MySQL - Algorithmic Visualization (Winter 2013)
- Taught Data Visualization, Website Development - Visual Communication (Fall 2013)

10.2012-03.2013 **Visus LLC.**(Santa Barbara, CA)
UX Design and Graphic Design Intern
- Redesigned NetSure Ticketing Service Website: Wireframe, Web Design, GUI Design
- Designed Visus LLC and XShot’s Visual Identity Design and Promotional Design

02.2012-08.2012 **CITS (Center for Information Technology and Society),** UCSB (Santa Barbara, CA)
UI Designer and Graphic Designer
- Redesigned CITS’s Visual Identity Design: Brand Identity Design with Logo design
- Redesigned and Implemented CITS’s Website design using Drupal.

03.2009-07.2010	**Design | Media Arts, UCLA**(Los Angeles, CA) Instructor and Teaching Assistant - Web Design (UCLA Summer Institute 2010), Taught HTML, CSS - Motion (Spring 2010), Taught After Effects, Premiere - Creative / Dynamic Internet (Spring 2009 - Winter 2010), Taught HTML, CSS, PHP
02.2003-02.2006	**SAMSUNG Design Membership,** (Seoul, Korea) Researcher and Intern for UX Design and Graphic Design - Developed New SAMSUNG Mobile UX Design and GUI Design – Samsung PAVV TV Premium GUI Development, New DMB Mobile UI Research and Design
02.2003-Present	**Freelance UX Designer and Multimedia Artist** (USA, Korea) - Developed iOS Mobile UX and UI Design, Graphic Design, Web Design and Multimedia Artworks for various clients in USA and Korea

AWARD

09.2015	**Fellows of Contemporary Art – Curator's Lab Award 2015**
08.2014	**Travel Award from Geumcheon Art Space, Seoul Art Space**
06.2014	**Doctoral Student Travel Grant 2014, University of California, Santa Barbara**
12.2012	**Asia Digital Art Award (ADAA) 2012** "Digiti Sonus" - Finalist Award
05.2012	**DaVinci Media Art Competition 2012 from Seoul Art Space –** Selected artist
09.2011	**UCSB Dean's Fellowship,** Full Scholarship for one year $20,000
05.2011	**2011 Arts Council Korea** - Residency award
03.2011	**The Vytlacil Campus of the Art Students League of New** York - the Artist-in-Residency (A-I-R) Program Scholarship
12.2009	**[13th] Japan Media Arts Festival,** Jury Recommended Work "One"
08.2009	**Adobe Digital Art Award (ADAA),** Semi-Finalist in Installation Design "One"
05.2009	**Dean's Office Scholarship** from UCLA Design | Media arts $4,800
03.2009	**Next Generation Design Leader 2009**in Korea Multimedia New Designer.
12.2008	**ADAA (Asia Digital Art Award) 2008**"Harmonia" - Excellence Award.
06.2008	**Korea National Scholarship,** Full Scholarship for two years $62,000
02.2008	**HCI 2008 Creative Award** "Color note (Ver.2)" - Selected Exhibition.
02.2007	**HCI 2007 Creative Award** "Sound Marbles" - The Second Prize.
10.2006	**Flash Animation Award** from Ministry of Environment of Korea "Monster" - Prize for Encouragement.
02.2006	**HCI 2006 Creative Award** "Picircle" - Selected Exhibition
12.2005	**Samsung Design Membership,** The Best of the Best.

PUBLICATIONS

2015

Han, Yoon Chung and Byeong-jun Han, "Digiti Sonus v2: New Interface for Fingerprint Data Sonification using Hand Motion," Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI 2015), Pages 363-366, April 2015.

2014

Han, Yoon Chung and Byeong-jun Han, "Skin Pattern Sonification as a New Timbral Expression," Leonardo Music Journal Vol. 24, December 2014.

Han, Yoon Chung and Byeong-jun Han, "Skin Pattern Sonification Using NMF-based Visual Feature Extraction and Learning-based PMSon", International Conference for Audio Display (ICAD) 2014, June 2014.

2013

Han, Yoon Chung and Byeong-jun Han, "Digiti Sonus" XYZN: Scale, ACM Leonardo Journal Vol. 46, No.4, July 2013.

Han, Yoon Chung, Byeong-jun Han and Matthew Wright, "Digiti Sonus: Advanced Interactive Fingerprint Sonification Using Visual Feature Analysis," Proceedings of New Interfaces for Musical Expression (NIME). 2013. (Full Paper)

Han, Yoon Chung, Qian Liu, Joanne Kuchera-Morin, Matthew Wright, and George Legrady, "Cloud Bridge: a Data-driven Immersive Audio-Visual Software Interface," Proceedings of New Interfaces of Musical Expression (NIME). 2013. (Poster)

Han, Yoon Chung and Byeong-jun Han, "Virtual Pottery: A Virtual 3D Audiovisual Interface Using Natural Hand Motions," Multimedia Tools and Applications, Springer Journal. 2013.

2012

Han, Yoon Chung and Byeong-jun Han, Digiti Sonus: An Interactive Fingerprint Sonification, ACM Multimedia 2012.

Han, Yoon Chung and Byeong-jun Han, Virtual Pottery: An Interactive Audio-Visual Installation, Proceedings of New Interface of Musical Expression (NIME), Michigan, USA, 2012.

2010

Han, Yoon Chung, "An Exploration of Sound, Mirror and Reflection" (MFA Thesis, University of California, Los Angeles, 2010.)

2009

Han, Yoon Chung, "One" BioLogic: A Natural History of Digital Life, ACM Leonardo Journal Vol.42, No.4, pp.372-373, 2009

2008

Han, Yoon Chung and Byeong-jun Han, "A Study on Interactive Sound Installation and User Intention Analysis_Focusing on an Installation: Color note," The HCI Society of Korea, 2008.

2007

Han, Yoon Chung and Suzung Kim, "A Study on Interactive Installation based on Sound and Color _ Focusing on an installation: Color note," ADADA International Forum in Fukuoka, 2007.

2006

Han, Yoon Chung and Suzung Kim, "A Study of Sound and Human's Interaction by New Media," ADADA(Asian Digital Art and Design Association) International Forum in Seoul. 2006.

Han, Yoon Chung and SeungHo Park, "A Study on the Human & Interaction of Actual Space and Virtual Space by New Media," Journal of Digital Design Vol.6 No.2, Korea Digital Design Society, 2006

EXHIBITIONS

09.2016	**ReSound,** Simons Center for Geometry and Physics, Stony Brook University, NY USA
10.2015	**L.A.S.T Festival** "Digiti Sonus" Stanford University, CA USA
09.2015	**"Globale Infosphere"** "Digiti Sonus" ZKM, Karlsruhe, Germany
04.2015	**CHI Interactivity exhibition**, "Digiti Sonus v2" COEX, Seoul, Korea
10.2014	**"Hybrid Highlights"** "Digiti Sonus" Museum of Art, Seoul National University, Seoul, Korea
09.2014	**"DaVinci Creative 2014"** "Virtual Pottery" Geumcheon Art Space, Seoul, Korea
08.2014	**"Sonic Trace"** The Second Solo Exhibition (supported by AliceOn), The Medium,

	Seoul, Korea
02.2014	**"Daily Reflections" at Total Museum,** “Digiti Sonus” Seoul, Korea
02.2014	**"Digital Media" at Cal Poly San Luis Obispo,** “Cloud Bridge” San Luis Obispo, CA USA
10.2013	**IEEE VisWeek Art Program 2013 (Selected),** Atlanta, Georgia, USA
07.2013	**ACM SIGGRAPH 2013 Art Gallery** “Digiti Sonus” Anaheim Convention Center, Anaheim, CA, USA
05.2013	**MAT End of Year Show 2013,** “Digiti Sonus”+”Cloud Bridge” Elings Hall, UCSB, USA
04.2013	**“Things That Turn Your Brains To Mush”, Santa Barbara Contemporary Arts Forum** “Tree Rings”+”Sound Tree Rings”, Santa Barbara, CA, USA
11.2012	**Seoul Mecenat and ArtsWalk 2012,** “Digiti Sonus” Seoul, Korea
11.2012	**Renewed Memories - Media Art Created with Personal Retrospective,** Arcade gallery, San Pedro, CA, USA
09.2012	**Media City Seoul 2012 DaVinci Exhibition,** Geumcheon Art Space, Seoul, Korea
08.2012	**NanoKorea 2012,** COEX, Seoul, Korea
05.2012	**MAT End of Year Show 2012, “**Virtual Pottery”, “Tree Rings” Elings Hall, UCSB, USA
01.2012	**“Tree Rings”** A Solo exhibition in gallery 479, UCSB, USA
10.2011	**Design Korea 2011,** Korea Institute of Design Promotion, COEX, Seoul, Korea
10.2011	**Soundwalk 2011, FLOOD,** Long Beach Downtown, CA, USA
09.2010	**INDAF (Incheon Digital Art Festival) _ Sense Senses,** Tomorrow City, Incheon, Korea
05.2010	**“Hello World” MFA Thesis Show,** New Wight Gallery, Broad Art Center, UCLA, USA
02.2010	**13th Japan Media Arts Festival,** The National Art Center, Tokyo.
12.2009	**"Are We Human?"** Inspace, The University of Edinburgh, United Kingdom.
10.2009.	**AFK(Away From Keyboard) UCLA Design | Media arts 2nd MFA Grad Exhibition,** New Wight Gallery, Broad Art Center, UCLA, USA
09.2009	**Collider: Interactivity and New Media,** The Emily Davis Gallery, Myers School of Art, The University of Akron, 150 East, Exchange St. Akron, OH. USA
09.2009	**The Fragments of Sound - 1st Solo Exhibition,** Artspace-hyun, South Korea
08.2009	**Videotage - "One" Yoon Chung Han's selected works with Erick Oh's animation,** Videotage, Cattle Depot Artist Village, Kowloon, Hong Kong
08.2009	**ACM SIGGRAPH 2009 Art Gallery** "One", Ernest N. Morial Convention Center, New Orleans, USA
07.2009	**"Five": Korean Young Artist,** "Jellyfish"+"Phonophobia", LA Korean Culture Center, LA, USA
05.2009	**4th Takeaway festival of DIY Media, "**Jellyfish", Dana Centre, Science Museum, London, UK
05.2009	**"Phonophobia"** - Solo Exhibition, EDA Grad Gallery, UCLA Design | Media

	arts, USA
06.2008	**MFA Degree Show** - "Harmonia", Samwon S&D Hall, SNU, South Korea
02.2008	**HCI 2008 Creative Award (Digital Art Exhibition)** - Visual Sound Installation "Color note (Ver.2)" Phoenix park, South Korea
09.2007	**Art Center Nabi P.art.y** Creative Commons Salon "CC Real Mixer,"A Visual Sound Performance "Interactive Hats" at Namsan Drama Center, South Korea
08.2007	**2007 Asia Association of Basic Design & Art Tsukuba** Exhibition "Mohoya" at Tsukuba University, Japan
08.2007	**Asia Digital Design Conference & Exhibition 2007** "Mohoya" at NID, India.
06.2007	**"insight in sight, insight in site**"_ A Conceptual Graphic Design "Mohoya" at Samwon S&D Hall, SNU, South Korea
02.2007	**"2 day exhibition of Media art and Design"** from Seoul National University "Sound Marbles" at UCLA Design | Media Arts, Los Angeles, USA
02.2007	**HCI 2007 Creative Award (Digital Art Exhibition)** -Tangible Sound Interactive Work "Sound Marbles" at Phoenix park, South Korea
01.2007	**Nabi Showcase 2007 (Making Sound)** - A Visual Sound Installation "3 Metronomes" at Art Center Nabi, South Korea
04.2006	**Processing work "Lines"** Woo-seok hall, SNU, South Korea
02.2006	**HCI 2006 Creative Award (Digital Art Exhibition)** -Image viewer interface design "Picircle" , Phoenix park, South Korea
12.2005	**BA Degree Show -** Image viewer interface design "Picircle" Samwon S&D Hall, SNU, South Korea
08.2005	**Global Design Membership Exhibition 2005 "Next society through design"** SADI Gallery, South Korea
02.2005	**SIG "4Dimension"** -Korean graphic design at SAMSUNG Design Membership, South Korea
08.2004	**Global Design Membership Exhibition 2004 "Self expressism"** _To Express Yourself with Innovation Concepts Mobile for Communication Media" Mobile Theraphy "Aigho" at SADI Gallery, South Korea
02.2004	**SIG "4Dimenson" Mobile power-on Moving Image Design,** SAMSUNG Design Membership, South Korea.

TEACHING EXPERIENCES

08.2015-Current	**Instructor** for class **"Computer Assisted Graphics"** in California State University, Fullerton (UI/UX design, Web and Mobile app design)
01.2016-Current	**Instructor** for class **"Graphic Design"** in California State University, Fullerton (UI/UX design, Graphic Design)

08.2015-12.2015 **Instructor** for class **"Special Studies in Graphic Design"** in California State University, Fullerton (Infographics, Data Visualization, Processing, Adobe Creative Suites)

01-05.2015 **Instructor** for class **"Interaction Design"** in University of San Francisco (Interaction Design, Game design, Processing, Java)

09.2014-05.2015 **Instructor** for class **"Introduction to Computer Programming"** in Academy of Art University (Basic Mathematics and Quantitative Analysis, Game design, Processing, Java,) https://www.academyart.edu/

01-03.2014 **TA** for class **"Algorithmic Visualization"** in UCSB Media arts and Technology, Instructor: George Legrady. (Processing, Data Visualization, Data mining, MySQL) http://vislab.mat.ucsb.edu/courses.html

01-03.2013 **TA** for class **"Algorithmic Visualization"** in UCSB Media arts and Technology, Instructor: George Legrady. (Processing, Data Visualization, Data mining, MySQL) http://vislab.mat.ucsb.edu/courses.html

09-12.2012 **TA** for class **"Visual Communication"** in UCSB Media arts and Technology, Instructor: George Legrady. (Processing, Data Visualization, Data mining, MySQL) http://vislab.mat.ucsb.edu/courses.html

06-07.2010 **Instructor** for class **"Web design"** in UCLA Design | Media arts Summer Institute 2010.
(Web Design, HTML, CSS)
http://dma.ucla.edu/SummerInstitute/2010/gallery/webdesign.html

03-06.2010 **TA** for class **"Motion"** in UCLA Design | Media arts, Instructor: Gareth Walsh (After Effect)
http://classes.dma.ucla.edu/Spring10/24/

01-03.2010 **TA** for class **"Dynamic Internet (Network Media 2)"** in UCLA Design | Media arts, Instructor: Chandler McWilliams. (Web Design, HTML, CSS, PHP)
http://classes.dma.ucla.edu/Winter10/161B/

09-12.2009 **TA** for class **"Creative Internet"** in UCLA Design | Media arts, Instructor: Chandler McWilliams. (Web Design, HTML, CSS)
http://classes.dma.ucla.edu/Fall09/161A/

03-06.2009	**TA** for class **"Creative Internet"** in UCLA Design | Media arts, Instructor: Casey Reas (Web Design, HTML, CSS) http://classes.dma.ucla.edu/Spring09/161A/
01-03.2009	**TA** for class **"Form"** in UCLA Design | **Media arts,** Instructor: Silvia Regon. (Design Composition, Two Dimensional Design, Materials and Form) http://classes.dma.ucla.edu/Winter09/22/

INVITED TALK & INTERVIEW

09.2015	Invited Speaker for seminar series, **University of Northern Denmark program,** Fullerton, CA USA
04.2015	Invited Speaker for seminar series, **School of Design and Human Engineering, Ulsan National Institute of Science and Technology (UNIST)**, Ulsan, South Korea
10.2014	Invited Speaker, **MOOGFEST 2014, Alternative Interfaces organized by Eyeo Festival**, Asheville, NC USA www.moogfest.com/speakers/yoon-chung-han
08.2013	Invited Speaker, **ACM SIGGRAPH Art Talk 2013**, Anaheim, USA http://s2013.siggraph.org/attendees/art-talks
08.2013	Invited Speaker, **ACM SIGGRAPH CG in Asia**, Anaheim, USA http://s2013.siggraph.org/attendees/birds-feather/events/cg-asia
08.2013	Interview with **PLANCCC** http://www.planccc.com/2013/07/01/yoonchung-han/
07.2013	Interview with **KOCCA** http://koreancontent.kr/1461
07.2013	Guest Speaker at UX Design class, **Seoul National University**, Seoul, Korea
09.2012	Guest Speaker at Musical Interface design class, **Graduate School of Convergence Science & Technology, Seoul National University**, Seoul, Korea
09.2012	Guest Speaker at Industrial Design class, **Korea University of Technology & Education**, Seoul, Korea
09.2012	Guest Speaker at UX Design class, **Seoul National University**, Korea

Abstract

Biometric Data Art: Personalized Narratives and Multimodal Interaction

by

Yoon Chung Han

Biometric technology has brought enhancements to identification and access control. As more digital applications request people to input their biometric data as a more convenient and secure method of identification, the possibility of losing their personal data and identities may increase. The phenomenon of biometric data abuse causes one to question what their true identity may be and what methods can be used to define identity and hidden narratives. The questions of identification and the insecurity of biometric data have become my inspiration, providing artistic approaches to the manipulation of biometric data and having the potential to suggest new directions for solving the problems. To do so, in-depth investigation of the narratives beyond the visual features of the biometric data is necessary. This content can create a close link between an artwork and its audience by causing the latter to become deeply engaged with the artwork through their own stories.

This dissertation examines narratives and artistic explorations discovered from one form of biometric data, fingerprints, drawing on insights from various fields such as genetics, hand analysis, and biology. It also presents contributions on new ways of creating interactive media artworks using fingerprint data based on visual feature analysis of the data and multimodal interaction to explore their sonic signatures. Therefore, the artwork enriches interactive media art by incorporating personalization into the artistic experience, and creates unique personalized experience for each audience member. This thesis documents developments and productions of a series of artworks, Digiti Sonus, by focusing on its conceptual approaches, design, techniques, challenges and future directions.

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Chapter 1

Introduction

1.1. Motivation

Every biologic organism has a unique body pattern. Examples include fingerprints, irises, palm prints, and faces. These distinct biometric patterns on the body represent a person's unique signature and identity. They are intuitive and powerful resources that represent the individual's genetic identity. There is no trick or filter to these patterns. The microscopic patterns that are generated and their complicated networks contain the truth of human birth, genes, and growth. Thus, these body patterns, known as biometric data, can provide a means not only for discovering our genetic code but also for exploring hidden narratives in relation with others.

In this digital era, the main problems with the use of biometric data are the misuse of personal data and privacy issues since the data contains information acquired from individuals. Sometimes, biometric data can be stolen for other purposes or crimes, which is a source of great concern in society. Although people are afraid of having their biometric data stolen, the use of biometric data is becoming more commonplace in this era due to the ease and convenience it offers as a method of verifying an individual's identity.

Systems across the world are tracking people's daily activities, online purchase histories, and personal relationships with others in many ways. And databases can be used to predict people's future actions and even control their future activities. Since biometric data originates from the human body, it is not easy to change or recreate the data itself. Once the data is acquired, the person's information, history, networks and even predicted future activities can be accessed, manipulated or erased. Thus, our biometric data is at once the most secure and the weakest information, which has the potential to cause many problems.

The questions of identification and the insecurity of biometric data have become my inspiration, providing an artistic context and becoming the main concerns in my artworks. As more digital applications request people to input their body data as a more convenient and secure method of identification, the possibility of losing their personal data and identities may increase. Furthermore, I assert that the identities acquired from biometric data are different from the ones determined by society such as a person's name, appearance, occupation, or social status. Biometric data contains natural-born individuality and unique genetic data patterns. The phenomenon of biometric data abuse causes one to question what their true identity may be and what methods may be used to define it. I believe artistic approaches to the manipulation of biometric data have the potential to answer those questions and suggest new directions for solving the problems with the use of biometric data.

In interactive media art fields, not many artworks have explored biometric pattern data as artistic contexts or materials so far. Often, the body motion data of audience members is detected using diverse sensing technologies (e.g. static body contours, dynamic body motion data, hand gestures, etc.) and used as an input in order to control interactions with pre-defined systems. The body data can represent an individual's unique behavior or temporally generated changes as input data in the feedback system. However, when different participants behave in a manner where their movements resemble each other, the results of the resulting data might be similar. The possibility that multiple participants could produce similar results would be a limitation and drawback of using the body motion data. Thus, media art audience does not necessarily achieve the high level of personalized experience as other applications of biometric data, such as a security system. As an artist, I am highly interested in the analysis and manipulation of the visual features of biometric data in order to explore the different identities of individuals based on the data and expand the diversity of personalized experiences between artworks and artists.

Therefore, the main goal of this research is to investigate in-depth narratives on the biometric data and explore how these contents can create a close link between an artwork and its audience by causing the latter to becoming deeply engaged with the artwork through their own stories. Especially, as a main artistic method, I believe that a sonic representation of biometric data can be a novel way of creating each person's sonic identity instantly, which is not as direct as a visual representation. Sound delivers various stimuli to the human body's sensory organs; it vibrates the body, allows one to listen to the sound via ears, and reverberates afterwards. A sonic experience is a powerful way to trigger strong emotions and easily recognize the differences in complicated units of information. This sensory transformation is the primary aspect of the process of artistic creation; in this research, visual features of skin patterns are acquired, manipulated and mapped into "sonic" output. The process of the transformation in this research encourages a possible way of creating a personalized experience for each member of the audience, thereby advancing toward another level of participation.

1.2. Problem Statement

Interactive media artists are engaged in changing the relationship between artists and their media, and between artworks and their audience. David Rokeby stated that they create relationships and systems, which contain feedback between participants and systems, and therefore there is a need to create the highest degree of indeterminacy and subjectivity in their experiences for better results. (Rokeby, 1995) Recent new media artworks have implemented advanced digital media technologies to enable more interactive communications and create indeterminate results for each participant while implementing diverse feedback systems. Thus, the audience's personalized feedback can be determined by their decisions made in the system. However, even though the artists implement open feedback systems and open-ended user interactions without any constraints, the interactive media artworks may not be fully personalized since they have limited contents in the open-ended containers. Biometrics technology has brought great enhancements to widespread personalized computing systems. In biological art fields, artists are able to implement feedback systems using bio image data, which enable active interactions, high indeterminacy and subjectivity in the artistic experience. Therefore, the use of biometric data can enhance the creation of an open feedback system and a more personalized experience. It can be used to explore genetically driven identities, which are hidden in the visual features of the data, having the potential to narrow the divide between the artworks and participants. This dissertation examines narratives and artistic explorations discovered from the biometric data, drawing on insights from various related fields and present contributions on new ways of creating interactive media artworks based on visual feature analysis of the data. The use of biometric data is proposed as a good solution to expand the range of the participants' experiences. Biometric data is non-replaceable, non-changeable, and genetically hybrid data, so it can be used to create individually unique and authentic experiences for each audience member. Furthermore, the hidden narratives behind the visual features of the biometric data are the important aspect of this dissertation. Biometric data is driven by the genetic code, however the correlation between the biometric data and the personhood should be compared and investigated to check if we could decode more meaningful context and enhance the personalized experience for each audience member.

Here I propose the term *"fingerprint data sonification"* to denote a novel form of personalized installation art and computational artworks that transform visual to audio, constructing aesthetic experiences using visual feature analysis, machine learning, and data sonification in both artistic and scientific ways. In this dissertation, a series of interactive media artworks investigate in-depth narratives beyond the biometric data in the artwork, and enrich interactive media art by incorporating personalization into the artistic experience. Through these explorations and avenues for further research, the work contributes to the growth of contemporary visual art practice. This is a research-oriented art form investigating the application of the sonified data systems that move towards an engaging aesthetic experience. I believe that such works are a promising method to suggest a new mode of communication and fulfill the individual's desire to create artistic experiences and sensory beauty.

It is rare to find previous research that transforms the visual features of biometric data into audio using both scientific and artistic approaches. In scientific and engineering research, in-depth analyses have been conducted regarding biometric data patterns themselves. However, a sonic approach to using biometric data has never been touched upon. Furthermore, in the artistic fields, it is rare to find cases where biometric data is used to create audio. Thus, this research is possibly a novel step on both biometric data sonification and personalized biomedia art.

1.3. Methodologies

This dissertation will develop a series of interactive media artworks that investigate the questions described above, in particular by using fingerprint data. Fingerprint data is not only the most accessible and easily obtainable data among many different kinds of biometric data, but it is also a great material and resource due to its unique visual features. More detailed reasons why fingerprint data was chosen will be described in Chapter Five.

The artworks produced in this dissertation are created based on reciprocal connections between theoretical research and art practice. The use of fingerprint data requires a significant understanding of the relevant knowledge and skill sets spanning scientific, biological and technical subjects. Previous scientific and theoretical research on the visual features of fingerprint data, its genetic relations, image processing techniques, and how to read and understand the visual features will be covered. Furthermore, appropriate data mapping methods and proficient technical implementation of image processing are necessary to achieve the goal of creating a personalized art experience.

However, it is difficult to guarantee that a good understanding of scientific knowledge and proficient technical development will create successful artworks and meaningful art experiences. On top of analyzing fingerprint data from a technical point of view, we need an in-depth investigation of the meaning, context, story, and correlation beyond the visual features of fingerprints. Genetic relationships, anticipated human behavior and personalities may provide ideas on how to analyze the stories about the past, present and future of human beings. These contents can create a close link between an artwork and its audience by causing the latter to becoming deeply engaged with the artwork through their own stories. In this dissertation, the contents discovered from fingerprint data are discussed from diverse perspectives and fields such as genetics, palmistry, and biology.

Each audience member will have individually different experiences, which nevertheless contain a coherent link with other people's experiences. In order to achieve this, the audiovisual outcome is produced to create individually different results. The audience members not only see their magnified fingerprint images but also hear the almost invisible image. Sonification mapping is a key aspect of differentiating sounds among similar groups of fingerprints. Various mapping strategies for data sonification will be discussed in Chapter Five. Furthermore, various approaches for differentiating sound and combining user interactions will be discussed to show what is or is not possible.

Since there has been very little previous research in the conjunction between biometric data and media art, it is hard to gauge whether or not the artworks are successful. (Please check Section 2.2.4 for related previous research) The creation of biometric data artworks, especially using fingerprint data, may possibly be a pioneering project in the field of media art, but at the same time it presents diverse challenges for an artist. While this dissertation is mainly for academic researchers and media artists, the main audience that experiences the artworks is the general public. Therefore, evaluations of its qualities can be made on different levels.

User evaluations will be conducted to review how the audience interacts with and experiences the artwork. Additionally, evaluations by professionals (media art researchers and exhibition curators in media art fields) will be included to support the importance of this research.

1.4. Structure of the Dissertation

This dissertation consists of six chapters. The introductory chapter describes the motivations and problems that led the author to investigate the topics in this dissertation. Since this dissertation focuses on both the artistic approach and technical implementation, Chapter Two discusses biometric data analysis and background research in conjunction with art and technology. It also focuses on the broad concept of personalization using body data, previous artworks in biologic art, and the concept and technical development of data sonification. Chapter Three describes the theoretical background, previous approaches and possible artistic investigation of biometric data visualization and sonification. Chapter Four shows the author's previous practice in creating personalized media art experiences in three different categories: biologic art, data sonification and visualization, and interactivity (audience's participation and personalization) After reviewing and analyzing the theoretical backgrounds and the practices, Chapter Five describes how the main artwork "Digiti Sonus" is created based on the theoretical research and analysis described above. The detailed descriptions of Digiti Sonus include: visual feature analysis of fingerprints, fingerprint data visualization and sonification, installation, floor design, interface design, and technical implementation. Finally, Chapter Six concludes with the results and future works of Digiti Sonus.

Chapter 2

Background

As this dissertation focuses on creating personalized narratives and multimodal interaction using biometric data, the following topics should be reviewed to create a novel form of installation art: personalized media art, identity, indexicality and biometric data, the human body as artistic medium, and biological art and technology.

2.1. Personalized Media Arts

2.1.1. Personalized Digital Experience

Modern digital media technologies have brought advancements to seamless human-computer interaction and human communication. In particular, widespread personalized computing systems already play an important role in diverse contexts including location-based services, recommender systems, commercial web-based services, and teaching systems. (Kay and Kummerfeld, 2012) Personalization in these systems is based on information about the user, making it critical to establish ways to address key problems related to personalization such as privacy, lack of personalization, and the many issue of existing user models and associated personalization. Kay, J. and Kummerfeld, B. argue the importance of scrutable user modeling and personalization, and describe how to solve the technical and interface challenges of designing and building scrutable user modeling systems. In modern systems, users enter their information not only by typing with a keyboard, mouse, haptic device, microphone, touch response display or similar device, but also by using more intuitive input devices such as multi-depth cameras, sensor-based tracking systems, and biofeedback sensors. Then, the corresponding algorithms process the information that is gathered, depending on the application, in order to create a personalized digital experience for each user. For example, human emotions can be recognized from facial expressions, gestures, or a combination of biological signals, which are used in diverse applications from music therapy to emotional avatars. (Sourina, Liu, Wang and Nguyen, 2011)

These personalized systems have been implemented in recent interactive artworks using a diverse range of advanced sensing technologies. The artworks collect data about each participant's characteristics such as their appearance or body movements using various cameras. This data is then stored in user profiles in order to create a database that utilizes a feedback system. The participants can control and manipulate the results based on their interests and preferences. The overall goal of these projects is to explore different participants' paths and personalize their experiences within a pre-defined system. The participant's contributions are the most significant part of this system since they control the variations in the results. However, in order to create successful results in the artworks, the linkage between the input data and output results should be meaningful. The goals of the arts are different from the goals of online services and commercial products, so the methods of creating personalization in the arts should be different. Also, the similarities and differences with other participants' results should appear significant to each participant. Personalized systems merely generate an indefinite number of results such as random numbers, which are not meaningful. Just as personalized digital applications suggest useful and more individualized information based on user profiles, the results from personalized artworks should have meaningful and unique outcomes. How can new media technologies in interactive artworks create significant differences based on participants' contributions for better personalization?

2.1.2. Definition of Personalization

Before discussing specific topics about personalization, the meaning and definition of personalization should be clearly defined to avoid any confusion in this dissertation. There are many definitions of personalization based on different fields and perspectives. Below are selected definitions that are relevant to this dissertation:

"Personalization is about building customer loyalty by building a meaningful one-to-one relationship; by understanding the needs of each individual and helping satisfy a goal that efficiently and knowledgeably addresses each individual's need in a given context." (Riecken, 2000)

"Personalization is the ability to provide content and services tailored to individuals based on knowledge about their preferences and behavior." (Hagen, 1999)

Both definitions primarily focus on personalization for the purpose of satisfying customers in commercial fields. However, in artistic fields, the target audience is broader and includes all users and participants who have no expectations of receiving a commercial service from the given system. In art installations, the users are members of the general public who want an artistic experience, gain aesthetic knowledge and closely interact with artists or artworks. Therefore, personalization in artworks should aim for more indefinite and subjective artistic experiences based on the data acquired from each audience member. The platform and medium for personalization can be expanded as well. Doug Riecken explains that personalization should not be restricted to the Internet but can include all kinds of user interfaces. (Riecken, 2000) He also argues that personalization does not need to create a limitation in a service or product by identifying each user. Users can provide their information anonymously, which can lead to various meaningful results. To elaborate upon this point, the definition of personalization in interactive artworks can be described as follows:

Personalization in artworks is about analyzing and designing each individual audience member's input, and providing indefinite and subjective contents based on the goals of the artists/artworks.

Personalization in web-based commercial services and artworks can be compared based on its various differences as described in Table 2.1.1.

Table 2.1.1: Difference on definitions of personalization in e-commercial service and artworks

Field	**Personalization in e-commerce services**	**Personalization in artworks**
Target audience	Customers or users who want to receive commercial services	Participants who want to have artistic experiences
Medium	(Mostly) Online	All kinds of interfaces
Goal	Provide better individualized service	Provide an aesthetically meaningful art experience
User information	Users agree to reveal their information and allow it to be stored.	Users can be anonymous. User information cannot be revealed.

2.1.3. Personalized vs. Personhood

As personalization in the scope of the arts is defined above, it refers to all interfaces that analyze a user's input to deliver an individualized outcome. However, can user input represent the characteristics of a real person? Or is it always changeable according to a user's preferences? If we assume the latter, how can we examine what the input data tells us about the real person?

Most personalized systems for commercial applications will analyze user information based on what the users provide as input for the system. The information that a user inputs could purely describe things about the real person, or it can be composed of fake or incorrect data, which is not associated with the real person at all. It all depends on the user's intentions. Users may even prefer to make up their own personas, which are completely different from their real identities. For example, a system can ask users for their personal information such as age, gender, location, personality, or current mood. Some users would want to create a different persona by entering new answers. This phenomenon is easily described by the term *parasocial interaction*. It is commonly referred to in mass media, television, or theater.

The term *parasocial interaction* is used in the current academic discussions on digital games and interactive media arts and design. In 1956, the term parasocial interaction was introduced by sociologists Donald Horton and Richard Wohl (Horton and Wohl, 2006) to describe interactions taking place in an interpersonal relationship between two parties; an audience member and a performer acting out a personality for the audience. It has frequently been argued that the following part of Horton and Wohl's definition is central to their concept of parasocial relationships:

...one-sided, nondialectical, controlled by the performer, and not susceptible of mutual development [...] These "personalities", usually, are not prominent in any of the social spheres beyond the media. They exist for their audiences only in the para-social relation. Lacking an appropriate name for these performers, we shall call them personae. (Horton and Wohl, 1956).

Due to the various effects that may arise from this parasocial interaction, it is hard to say that a user's input data can be read to understand the real person. Even though users may intend to enter their personal information carefully, there are still parts that may be missing from a complete description of the real individual.

The other question is whether or not the answers intended by the user are appropriate for creating good personalized artworks. It all depends on what kinds of data users enter into the system. The input data for commercial products most likely includes the users' preferences, opinions, choices, values and feelings. Commercial products and artworks have different goals. For commercial products, useful and productive answers about the customers must be gathered, but in artworks, the artist is trying to convey an intended message. Communication between artworks, artists, and the audience is the most significant aspect of artworks. In interactive media arts in particular, this communication becomes more dynamic and interactive, so the final results can be hard to predict. Most participants in art exhibitions would have some expectations about the artworks before entering. However, once they learn and experience new things from the artworks, the feedback between the interactors and the system can create the highest degree of indeterminacy and subjectivity, which leads to a higher level of user engagement. Based on this fact, the user's intended input data might limit the scope of creating a dynamic personalized art experience if the input data is not sufficient, biased, or representative of the users. However, if the input data describes the users well by using their inherited data, the artworks can create closer a relationship with each audience member. Additional features to control the inherited input data or manipulate the data by adding user intended data would create more subjective results. Therefore, creating successful artworks depends on the types of input data entered by each audience member in an appropriate way to create a meaningful art experience.

In this dissertation, in order to enhance the personalization in artworks and create meaningful experience, inherited data is primarily used since it is closely associated with the audience members and each audience member can discover unexpected results without the need for prior input. Once their inherited data is acquired, users can manipulate the data by entering their intended data, which will broaden the scope of the users' decisions. In this dissertation, biometric data will be used as the inherited data. Biometric data is a great resource to represent individuals with its visually distinguished features. It is commonly used in industries and engineering. However it is unclear that the biometric data can tell the personhood since it is individually unique data with visual characteristics, however it can be used only unique identifiers without linkage with the person. However, a significant number of biometric data can tell societal implications and correlation with others, which are the important aspect of the use of the biometric data. More details on this issue will be described in Chapter Three.

2.1.4. Personalized / Individualized Art

Personalization in artworks is not a new aspect of artistic fields. It has always been an aspect of traditional arts such as painting, sculpture, or installation arts. Spectators experience different emotions, interpret the artworks in their own ways, and learn new ideas. It all depends on their personal choices, decisions, preferences, and previous experiences. In an essay "Death of the Author," (Barthes, 1978) Roland Barthes argues against the practice of traditional literacy criticism on incorporating the authors' intentions in texts, and instead argues that writing and creator are unrelated. According to Barthes, writing texts is no longer the same to recording and representing contents, but instead it is much closer to performing, which the act with no content. Also, he mentioned that the time when the author wrote the text is no longer the same as an illustration shows in Figure 2.1.1. There's no other origin since all the text creates many dimensions based on a variety of sources of culture. The core part of the writing becomes reading to reveal the new interpretations on the multiple dimensions and layers of writings. The reader becomes the destination where doesn't have any background or history, but has a right to constitute the text. This concept of Barthes can be applied to the relationship between artworks and the audience in terms of creating personalized experiences and interpretations.

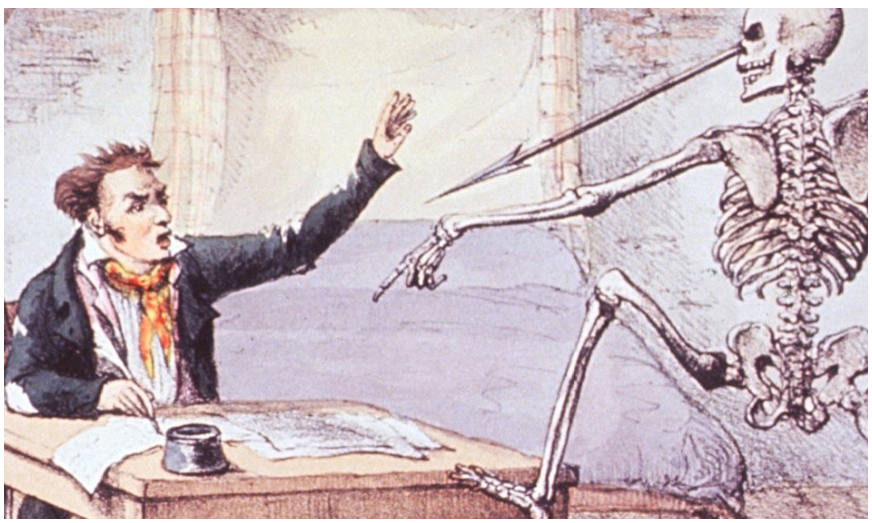

Figure 2.1.1: *Death Found an Author Writing His Life*, Edward Hull, 1827 [i]
Image in the public domain.

However, in this dissertation, the main focus of personalized art means something different. It is about producing personalized outcomes that are driven by each individual audience member. The outcomes can create customized art experiences, which cannot be reproduced or copied without identical conditions and identical input by the same spectator. The artworks do not produce the same output for every audience member. Therefore, personalized art is not limited to creating a personalized internal experience between artworks and spectators. It does not limit the emotional or physical experience that each audience member may have while interacting with an artwork. Art experiences can occur in two ways: 1) internal, emotional, and indirect experiences, and 2) external, sensory, and direct experiences. Internal personalized art experiences have been commonly observed and created in non-interactive traditional arts such as painting, sculpture, drawing, installation and non-interactive video art. External personalized art experiences appear when interaction between the audience, artworks and artists is created.

Since new media technologies are used by artists as their artistic medium and technique, diverse interactions and types of user engagement have become possible for interactive media arts. Furthermore, each audience member can achieve a different aesthetic experience. By using interactive media, the audience can become a part of the artworks. According to David Rokeby, key elements are required to generate more personalized interactions in interactive media arts. (Rokeby, 1995) The key elements are:

- Construction of subjectivity
- Feedback loop system
- Interaction
- Freedom vs. control

Technologies establish two-way communications between two parties, which are not symmetrical. This is called interaction. (Galloway and Thacker, 2007) Through interaction, scientists or programmers can physically change the system by inserting new data sequences, so both communicative pairs or multiples can be changed. It is different from the DNA sequence, which is the informatics code that governs the development of physical life. Interaction manipulates the protocols for the artworks to alter the communication between the interactors, artworks and the system of the artworks. User interaction in interactive media artworks is created in an open loop system, which creates subjective and unique experience for each individual. It updates the system by inputting new contents and generating updated contents in association with the previous contents. Thus, the system is constantly evolving like an artificial life form to create personalized output for each audience member. The construction of subjectivity is the main focus of interactive artworks. In order to create personalized experiences, a system of constructing subjectivity should be designed. Furthermore, depending on the feedback from the users, the system consistently cycles through the same procedure of creating subjective input and output. In order to create such a feedback loop system, artists should design the system carefully by creating many parameters in the system. Limited restrictions would be necessary. In order to create a feedback loop system, Alexander R. Galloway and Eugene Thacker suggested an examination of the alternative logics of control instead of arguing an open/closed opposition. (Galloway and Thacker, 2007) They explained that the open control logics associated with computer code or Internet protocols use informatics control or material-model control to enhance user interactions.

Table 2.1.2: Four modes of interaction in interactive media arts as described by David Rokeby (Rokeby, 1995)

Mode of Interaction	Description	Examples
Navigable Structures	Articulation of a space, whether real, virtual or conceptual. The artist structures this space with a sort of architecture and provides a method of navigation.	Jeffrey Shaw's "The Legible City," Chip Morningstar and F. Randall Farmer's "Habitat"
The Invention of Media	Blurs the boundary between the artist and the audience. The interactor becomes a creator.	Myron Krueger's "Videoplace"
Transforming Mirrors	Representation of the spectator on a video projection or screen, The myth of "Echo and Narcissus".	Chico MacMurtrie and Rick W. Sayre's "Tumbling Man", David Rokeby's "Very Nervous System"
Automata	Creations are essentially self-motivated and autonomous, and have individual entities.	Norman White's "Helpless Robot", Norman White's "Facing Out, Laying Low"

David Rokeby stated that there are four different kinds of models of interaction: navigable structures, the invention of media, transforming mirrors, and automata as shown in Table 2.1.2. (Rokeby, 1995)

This dissertation uses biometric data, which comes from the human body, so it can be categorized under the "transforming mirrors" mode. Numbers and images generated from the biometrics can be a mirrored representation of human beings, mimicking them and discovering hidden narratives in their physical bodies. The representation and identity of human beings created from biometric data is a controversial issue in this digital era. Due to the uniqueness and originality of biometric data, it is commonly used in many digital applications. Recently it has been used in artworks to address problems related to surveillance, identity theft, and privacy issues. Despite the controversial issues surrounding biometric data, the use of biometric data can greatly expand the boundary of subjectivity in interactive media arts. The materials and input contents for feedback loop systems can be opened with low limitations, and biometric data is unique and non-replaceable. More details on identity and biometric data in media artworks will be described in the next section.

2.2. Identity, Indexicality and Biometric Data

2.2.1. Identity

Life histories have become more secure as they are increasingly bound up with databases and digital systems. (Jones, 2006) In theory, data does not degrade, so electronic memories do not fade. However, in practice they have become more fragile and more vulnerable to accidental erasure, intentional manipulation, and degradation or distortion of various kinds. (Jones, 2006) In order to solve these issues, users often set up their personalized accounts so that they match their identity with their data. There are various ways to verify one's identity using many personalization techniques. In the online environment, a typical method is to enter a username and password combination, which avoids giving a physical token to users, such as numbers. (Ghosh and Dekhil, 2007) Therefore, users can authenticate themselves using the identification method. However, these days there are many cases of identity fraud, identity theft, and hacking, which show that personal digital records are frequently and easily used in illegal ways. In response to fears over such crimes, government agencies propose the use of "biometric" information as an access key, using a system that is designed to secure our identity permanently. Users don't have to create their own identification anymore, but only provide what they are given by genetics and birth. Matching real bodies with their digital "shadows", such as iris patterns, fingerprints, and tooth X-rays, the system will confirm our identities to prove "who we are." The questions raised by the biometric data are: What can we read and learn about ourselves with the data? Do they contain all life histories and data in secure ways? What will happen when the biometric data can also be copied or intentionally manipulated? Are they simply superficial copies of our identities or one of the many methods used to index each person using biometric data images such as numbers? Caroline Bassett asserts that digital interpellation can reduce the complexity of life to a single line in a database entry. However, this may lose the various narrative identities we might organize for ourselves and result in a form of identity theft. (Jones, 2006) There are, of course, ways in which digital media can expand the narratives of identities, but it may still be used to conceal identity theft instead of contributing to the natural growth of our identities.

2.2.2. Indexicality and Biometric data

When matching biometric data with real identities, the relationship between one's biometric data and identity can be *indexical*. In linguistics and the philosophy of language, *indexicality* refers to an indexical behavior or utterance which points to some state of affairs. For Charles Sanders Peirce, *indexicality* is one of the trichotomy of signs (Symbol, Index and Icon). (Peirce, 1932) "Symbol" means that the physical vehicle and referent are connected by convention (e.g. habitual usage). "Icon" means that the physical vehicle is related to the referent through a shared quality (e.g. a circle that represents the sun). However, "Index" means that the physical vehicle is a trace left by the referent, and the best example of an index is the fingerprint. A fingerprint is an identifier and an index written by genetics and nature that corresponds to each living creature. Peirce also mentions that the photographic medium is another index since it uses evidence, and the image that appears in a photograph corresponds to reality. According to Jens Hauser (Vanouse, 2011), biometric data such as the fingerprint is an indexical, imprint-based medium based on Peirce's theory, and it shows complex banding patterns and unchanging natural data. (see Figure 2.2.1) Thus, imprinting biometric data images and deconstructing the nature of genetics through the images can be directly and physically connected with things, commonly termed "indexicality."

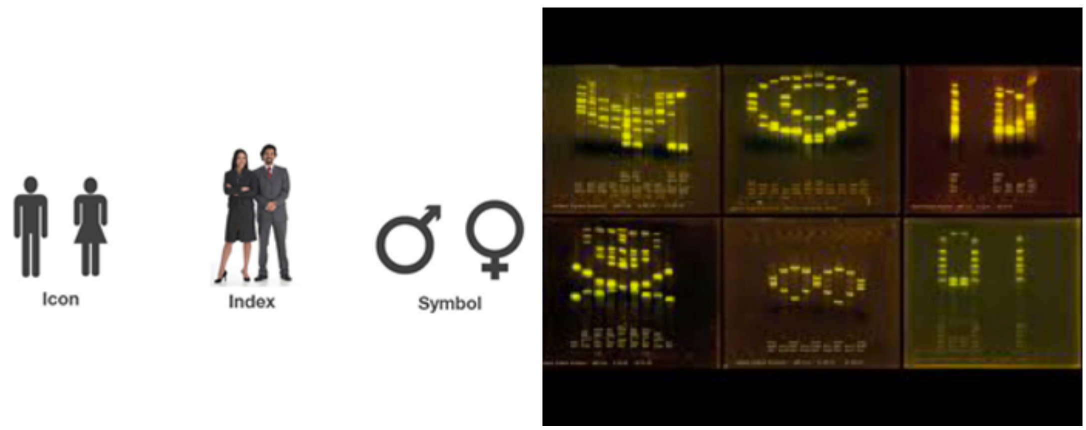

Figure 2.2.1: Peirce's Trichotomy of Signs (Left): Examples of Icon, Index and Symbol. Image in the public domain. (Right): *Latent Figure Protocol*, Paul Vanouse, 2011 (Vanouse, 2011)

The indexicality of language refers to the linkage between the language and the situation of use for determining the significance of what is being said. (Ochs, 1990) Language and culture are evolving and changing in situations as digital media technologies develop at many levels. Thus, the ways of interpreting our identity data can be reorganized and interpreted in different forms and systems. The use of biometric data shows the close linkage between personhood and observers based on the idea of the indexicality of language. Significance and important meanings in the context of biometric data can be observed through analysis of the biometric data without any filters or manipulations in between the traces and personhood. This is the main reason why biometric data is used in this research.

2.2.3. Trace, Imprint, Index and Identification

Biometric data conveys the idea of uniqueness of individual or groups, national identity, of unique personhood, of individuality, or crime scene traces, of criminal investigation. According to Simon A. Cole (Vanouse, P., Cole, S.A., and Hauser, J., 2011), the notion of "criminal identification" itself has ambiguity based on these three aspects:

"1) identify the author of a criminal act (trace) 2) to bureaucratically fix an identity to a "subject" or "criminal" subject of the state (an imprint), or 3) to "pre-identify" individuals with criminal propensities (an index)." (Vanouse, P., Cole, S.A., and Hauser, J., 2011)

Simon mentioned that all of these forms of "identification" have a notion of "revealing." (Vanouse, P., Cole, S.A., and Hauser, J., 2011) The identification technology is capable of revealing the hidden truth of bodies. For examples, forensic techniques such as fingerprinting can read what is hidden from what is invisible. Hidden truth, hidden identity, hidden character – these are the concealed attributes rendered visible by proper interpretation of surface traces (Vanouse, P., Cole, S.A., and Hauser, J., 2011) To achieve the identification of the personhood, it needs comparisons and analysis with, crucially, database, collections of biometric data along with personal information achieved by the state or country.

The true character can be revealed by several technologies and theories in pseudo-science fields. Phrenologists and craniometrists believed that heredity, race, ethnicity and character could be read in shapes and sizes of human skulls. Phrenology is a process that involves observing and/or feeling the skull to determine an individual's psychological attributes. Franz Joseph Gall believed that the brain was made up of 27 individual organs that determined personality (Parssinen, 1974) From absolute and relative sizes of the skull the phrenologist would assess the character and temperament of the patient. (see Figure 2.2.2. Left)

Francis Galton attempted to create a system to groups of people based on the heredity, via a method of composite photography. He captured an arbitrary number of individual portraits of chosen groups of people, and controlled exposure time to the portraits. Through the technique of photographic superimposition of two or more faces by multiple exposures, the composite process resulted in producing a slightly blurred image and created imaginary figures that represent specific groups of people. Francis Galton believed that ”Composite Portrait” can categorize individuals in different types such as “criminal types” It was an extension of the statistical techniques of averages and correlation. (Galton, 1878) His approach was one of the first implementations of convolution factor analysis and neural networks. It repeatedly occurs in the area of popular science. Galton asuggested that the technique could be used for creating natural types of common objects as shown in Figure 2.2.2. (right)

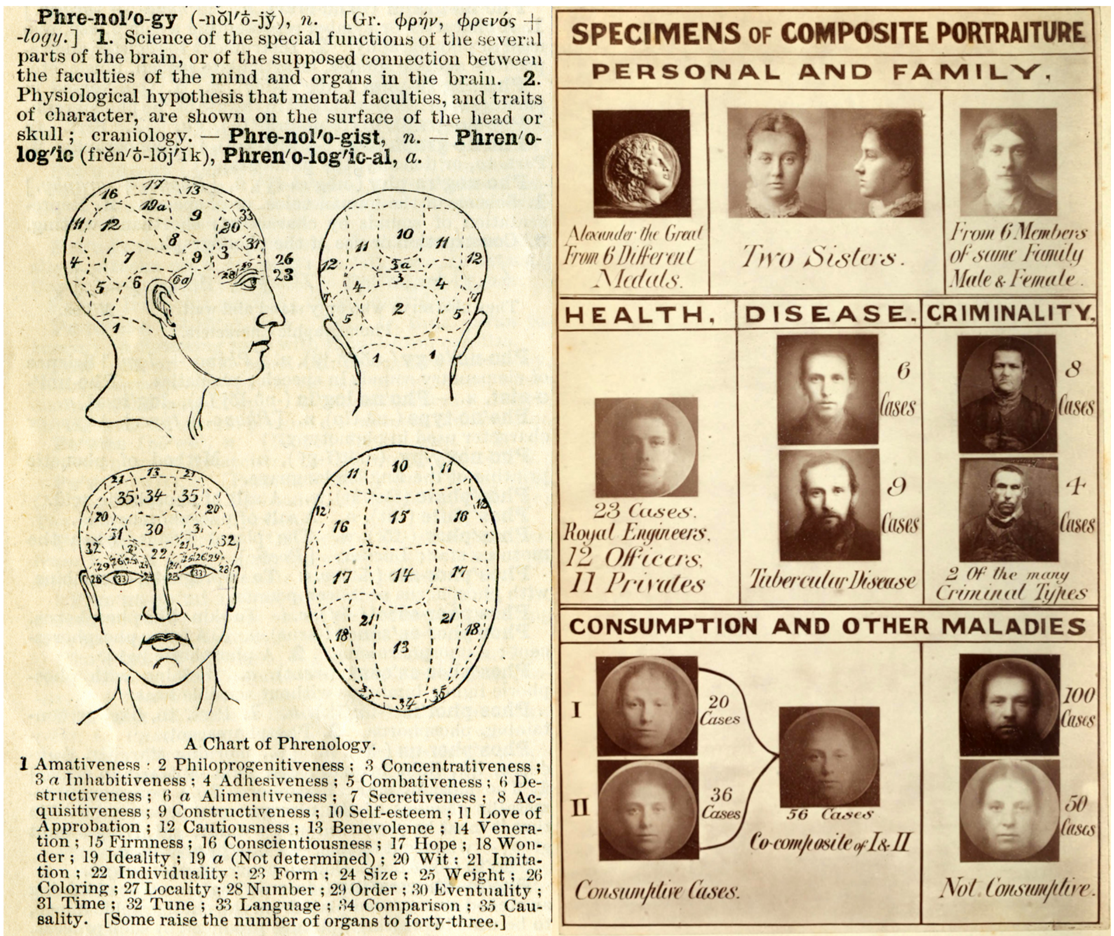

Figure 2.2.2: (Left): A Definition of Phrenology with Chart Webster's Academic Dictionary, circa 1895.[ii] (Right): *Composite Portraiture*, Francis Galton, 1883[iii]. Images in the public domain.

As seen in these previous historical approaches, many people have concerned about the reading of race, character, and narratives into genetic traces. Art is always trying to reveal the artist's personal truth, social or political voice. Many artists use traces, imprints and index of bodies to reveal hidden narratives, hidden truth and identification of ourselves in the society using the physical traces based on semiotic approaches of the early modern identification system.

2.2.4. Use of Biometric Data in the Arts

Biometrics authentication is used to identify and verify individuals by using standardized measurements of specific body parts or features, such as a fingerprint, iris, face, voice, or gait recognition, with the goal of extracting a core identity, or truth, from the body. Although the biometrics has been used in computer science and related fields for a long time, the use of biometric data is relatively new in the arts, arising through the use of technology to detect and analyze the biometric data. Several studies present good approaches to using biometric data in art practices.

Figure 2.2.3: *Latent Figure Protocol*, Paul Vanouse, 2007-09.[iv] (Left) Figure was produced with the DNA of bacterial plasmid pET-11a. Enzymes used to process the DNA are listed in each column. (Right) Installation at CEPA Gallery, Buffalo, 2008. Images used by Permission

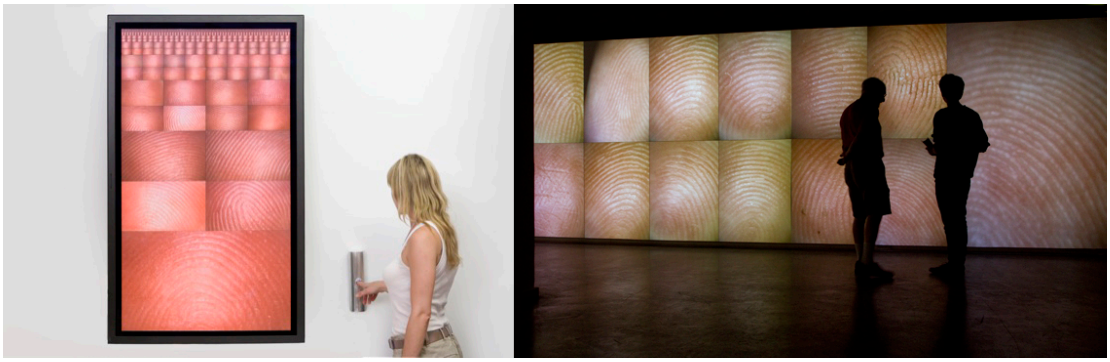

Figure 2.2.4: *Pulse Index*, Rafael Lozano-Hemmer, 2010.[v] Photos by: Antimodular Research. (Right) Shown here: Recorders, Museum of Contemporary Art, Sydney, Australia, 2011. Images used by Permission

Paul Vanouse explored how DNA samples can create emergent representational images in his work "Latent Figure Protocol." (Weibel and Fruk, 2013) This artwork not only challenges the code of contemporary media knowledge production, but also questions scientific methodologies in general, especially how society interprets them. (see Figure 2.2.3) These methodologies are revealed to be devices for scientific analysis, transforming into synthesizing media and therefore being highly contracted. This directly shows the results of the laboratory process as an "iconic" resemblance. Rafael Lozano-Hemmer uses fingerprints in his work "Pulse Index" (Rafael Lozano-Hemmer) to indicate each visitor's ID as indexical data. (see Figure 2.2.4) Fingerprint data recorded from the audience becomes part of the artistic contents, creating patterns based on the Fibonacci sequence. The artwork detects participants' heart rates to display the cells of the fingerprint images. Depending on the input from the participants, the visual composition displayed on the screen consistently changes, and the database is updated in a manner similar to a security system, which typically uses biometric images for identification.

Figure 2.2.5: (Left) *Facial Weaponization Suite*: Fag Face Mask - October 20, 2012, Los Angeles, CA, photo by Christopher O'Leary (Right) *Data Masks*, Sterling Crispin, 2014. Images used by Permission.

Facial recognition is one of the controversial issues in society due to critical problems regarding privacy. It functions by generating 3D models of faces and mapping unique visual features, such as measuring the distance between the eyes or the width of the nose, and analyzing skin texture. Since surveillance camera systems are prevalent across the world, attempts have been made to identify people and analyze their movements and behavior. Media theorists Alexander R. Galloway and Eugene Thacker described the "universal standards of identification." (Galloway and Thacker, 2007) This refers to technologies of identification that index human activity and identity using biometrics, GPS and data-mining algorithms, which then operate as common templates for regulation, management, and governance. Zach Blas created an artistic project, “Facial Weaponization Suite” (Blas, 2014), which protests against biometric facial recognition and governmentalities of the face. (see Figure 2.2.5, left) The biometric facial data of participants aggregated to produce each mask, and participants wore the masks in a given workshop as a collective protest and performance. It is made unrecognizable by preventing biometric facial detection in order to reject political visibility and representation. It also prevents any calculations and categorizations of the face. Sterling Crispin also created “Data Masks” (Crispin, 2014) to investigate the form and function of biometric surveillance technology, which is the mathematical analysis of biological data. (see Figure 2.2.5, right) Crispin is concerned with the aggressive overdevelopment of surveillance technology, and how it is affecting human identity. He reversed the process of facial recognition, facial detection and image correlation techniques and created unrecognized face masks.

2.3. Bio Art and Technology

The previous section discussed the indexicality of biometric data and how it has been applied in art practices. Even though this paper focuses on the use of biometric data, there is not much previous research on biometric data artworks yet. Thus, bio art, which encompasses a broader scope than biometic data, should be discussed to examine diverse conceptual approaches, technical implementations in the arts, and the impact on the arts. In this section, the general concepts, categories, and characteristics of bio art will be discussed.

2.3.1.Bio Art

Bio art (or biological art) is a new genre of contemporary art that uses living matter and the processes of life. According to Eduardo Kac, (Kac, 2007) bio art employs one or more of the following approaches:

"(1) the coaching of biomaterials into specific inert shapes or behaviors; (2) the unusual or subversive use of biotech tools and processes; (3) the invention or transformation of living organisms with or without social environmental integration." (Kac, 2007)

Bio art mostly uses living matter and the properties of life and its materials, changes organisms within their own species, or invents life with new characteristics. Living organisms go through various living processes from birth or generation to reproduction, growth, manipulation, replication, and death. Bio art depicts the various living processes and goes beyond to examine how living organisms affect cultural patterns, interact with the environment and experience symbiosis.

Bio art is a unique field in contemporary art, which did not exist before. It highlights the distinct traits of living organisms and the fundamental processes of life. Eduardo Kac states that bio art cannot be classified as ready-made, conceptual art, situationism, or social sculpture. (Kac, 2007) It creates not just new objects, but new subjects since it focuses on the dialogical and relational as much as the material and formal qualities of art. Table 2.3.1 describes various differences between contemporary art and bio art.

Table 2.3.1: Differences between Contemporary Art and Bio Art based on Eduardo Kac (Kac, 2007)

	Contemporary Art	Bio Art
Objects	Produced objects (painting, sculpture, ready-made)	Living materials, reproduced or transformed materials, intervened bio-materials
Environments	Installation, land art	Natural environments for biological processes
Events	Performances, happenings, telecommunications exchanges	Open to the entire gamut of life processes and entities, from DNA modules and the smallest virus to the largest mammal and its evolutionary lineage.
Materials	Immaterial works (videos, digital pieces, websites)	Ontogenetic works (organism development, species evolution, life processes and entities)

Bio art has been the theme of many exhibitions and conferences where art and technology converge. Many international exhibitions have created themes around biologic art to present works under various topics such as art, biology, bio-technology, artificial creatures, nature, nano-technology, living organisms and biometric data. SIGGRAPH Art Gallery in 2009[1] (Malina, 2009) chose artworks under the theme of biologic art in which biological forms and life processes were grafted together with digital code and devices. International conferences, such as Naturally Hypernatural: Visions of Nature[2] hosted by the Bio Art Lab at the School of Visual Arts, are some of the representative events that show the cutting edge of bio art. Mediated Matter Lab (Mediated Matter Lab) explores nature-inspired design along with computational design, digital fabrication, material science and synthetic biology. Their research involves biologically inspired fabrication and nature-based forms, and explores new forms of design and novel processes of material practice at the intersection of computer science, material engineering, design and ecology.

Suzanne Anker is a pioneering bio artist and the chair of the Bio Art Lab at the School of Visual Arts. In her article (Anker, 2014), she defines three sub-categories of bio art:

"1) imagery garnered through photographic methods, 2) the incorporation of 3D computer modeling with an interest in emergent theories of life, and 3) online laboratory practices." (Anker, 2014)

[1] Link: http://www.siggraph.org/s2009/galleries_experiences/biologic_art/
[2] Link: http://naturallyhypernatural.sva.edu/

Table 2.3.2: Three sub-categories of Bio Art based on Suzanne Anker (Anker, 2014)

Sub-Categories of Bio Art	Description	Technique / Medium	Formats of Artworks	Representative Bio Artists
1. Imagery garnered through photographic methods	Through photographic techniques, artworks explore images of chromosomes, body scans, and genotypic and phenotypic variations.	MRI, atomic force microscopy, electrophoresis, gene sequencing and PCR technologies	Painting, sculpture, photography, video, music and theater	David Kremers, Marc Quinn, Marta de Menezes, Regina Trindade, Joe Davis
2. Incorporation of 3D computer modeling with an interest in emergent theories of life	Explores emergent theories of life through modeling software	3D computer modeling software, artificial life, robotics, biodegradable scaffolding	New media Installations, rapid prototype sculptures and algorithmic code	George Gessert, Natalie Jeremijenko, Heather Ackroyd, Dan Harvey, Brandon Ballengee, Oron Catts, Object-Oriented Art (Marion Laval-Jeantet and Benoit Mangin)
3. Wet laboratory practices	Observe, explore and manipulate living organisms in artistic ways through laboratory practices	Typical apparatus in laboratories	Living matter as the medium	Paul Vanouse, Paul Perry, Ionat Zurr

Each sub-category uses various methods, techniques and have different representative bio artists. More details can be found in the Table 2.3.2 above.

The topics of the bio art ranges from DNA molecules and the smallest virus to the largest mammal and its evolutionary lineage. Table 2.3.3 shows a list of the artists and representative artworks based on the topics:

Table 2.3.3: A list of bio artists and artworks based on the topics (Kac, 2007)

Topics	Artists	Representative artwork
Bacteria	David Kremers, Marc Quinn	David Kremers *Paraxial Mesoderm*, 1992
Proteins and genes	Regina Trindade, Joe Davis	Joe Davis *Bacterial Radio,* 2012
Manipulated plants	George Gessert, Natalie Jeremijenko, Heather Ackroyd, Dan Harvey	Natalie Jeremijenko *One tree(s) project,* 2000
Tissue culture	SymbioticA (Oron Catts and Ionat Zurr), Object-Oriented Art (Marion Laval-Jeantet and Benoit Mangin)	SymbioticA *Victimless Leather,* 2004
Developing breeding projects	Brandon Ballengee	Brandon Ballengee *Collapse,* 2012
Somatic modifications	Marta de Menezes	Marta de Menezes *Nature?,* 1998-2000
Typical apparatus in laboratories	Paul Vanouse, Paul Perry	Paul Vanouse *Ocular Revision*, 2010
Fewer organisms or material, more general approach - Biological irreverence	Adam Zaretsky, Eduardo Kac (trans-genesis)	Adam Zaretsky, *Humper-Discoverer*, 2000

2.3.2. Human Body as Artistic Medium

The media theory of Marshall McLuhan defines media as an extension of the sensory organs (McLuhan, 1964) Just as the wheel is seen as an extension of the foot, the telescope and microscope are aids for people to see further and deeper than was possible with the human eye. Media art produced by the new equation of media, data, and man places human beings in a new relationship with their environment. Media art allows an artist-scientist, such as Leonardo Da Vinci, to pursue their agenda in a new context, with new technological and scientific means. (Weibel and Fruk, 2013) The human sensory organs serve as interfaces to the given natural world in which we live. However, as media technologies have evolved, media as an artificial extension of the natural organs changes both the ratio of our sensory organs and the relationship of our sensory perception to our environment. Due to the invention of the microscope, artists were able to investigate the invisible world in their bodies, and raise questions about the boundaries between the aesthetics and meaning of science and art. Mark Boyle and Joan Hills (Locher, 1978) explored microscopic images of body fluids in their work “Light Projections at UFO Club” in 1967. Eduardo Kac’s work “Genesis” (Weibel and Fruk, 2013) explored the intricate relationship between biology, belief systems, information technology, dialogical interaction, ethics, and the Internet. He created his own synthetic gene by translating a sentence from the biblical book of Genesis into Morse code, and converted the Morse code into DNA base pairs. The genesis gene was incorporated into bacteria, and participants could change the biblical sentence in the bacteria. Victoria Vesna and James K. Gimzewski created "Zero@Wavefunction" and "Nano" installations (Vesna and Gimzewski, 2005) based on the way a nano scientist manipulates an individual molecule projected on a monumental scale. Visitors interact with a projection of a larger, more active and responsive molecule, which responds to the movements of the person's shadow and allows manipulation of the molecule.

The body can be extended or we may even create artificial creatures based on our bodily gestures. Stelarc's "Internet Ear" and "Extra Ear: Ear on Arm" (Hauser, 2008) extend a body organ to a new extra position, by attaching a new ear on the left arm that not only hears but also transmits. It became enabled as an additional ear that was effectively an Internet organ for the body. In "A-Volve" by Christa Sommerer and Laurent Mignonneau, an artificial nature is created by drawing a 2D contour by hand which then transforms into 3D living creatures that undergo birth, life and death. (Sommerer and Mignonneau, 2005) "Nuclear Family" by Marta de Menezes (Menezes, 1998) focuses on genetic differences between human beings from different groups, which are represented using DNA microarrays. The groups can be defined based on physical characteristics, such as "dark eyes", "blond hair", and "disabled", or non-physical characteristics, such as "nationality", "religion", "vegetarian" or "wealthy". Although genes are not the only factor determining who and what we are, she believes that it is one of the most important elements in giving us common features. In "Nuclear Family", a group of open cubes is shown inside the gallery, each one corresponding to a different group. The visitors are invited to experience the installation from within a cube corresponding to a group where they feel included.

These days, society controls individuals cognitively and physically in what Foucault described as “biopower” or “biopolitics.” (Foucault, 1997) Contemporary biotechnology has allowed the minutest elements found inside the body (e.g. genes) to be externalized (through gene sequencing and amplification), and that which is created outside (e.g. a synthetic chromosome) to be internalized (transgenics). In this new realm, we no longer exist in our current physical body, but certain features in our body can be transferred to other human beings, or other different kinds of creatures (e.g. animals). Biotechnolocial developments for genetics, reproduction and synthetic bio studies have affected not only the health of the individual but also social relations. Biotechnology can manipulate our lives and create new life. Our nature and culture will no longer be the same anymore, but rather it will open up the blurry boundaries between life, creatures, culture and society. Mutation, selection and competition as evolutionary processes will become more active, combining different species and complex ecologies. Considering this phenomenon, the human body is not the only area that can be explored. Diverse living organisms and virtually created creatures are the next topics. Artists have explored the creation and manipulation of various living organisms to examine how biotechnology has altered our societies and cultures. In the next section, diverse approaches to using biotechnology and living organisms will be discussed.

2.3.3. Art and Biotechnology

Biotechnology is a technique using living organisms or parts of living organisms to fabricate or modify things: make products, improve plants or animals, develop microorganisms, or carry out acts of a biological nature. (Kac, 2007)

One of the unique contents used in the biotechnology is microorganisms. Microorganisms have become significant material sources due to the aesthetics and unique aspect about "life" for artists, designers and scientists. Microscopic images of bacteria have commonly used for artworks, design, commercials and photography. As a pioneer of the works, Alexander Fleming, the father of penicillin, used microbes to create interesting photography. Suzanne Anker mentioned that,

"Using microbes that were differentiated by color, Fleming was able to have his various microbes "bloom" at the same time, thus portraying a rich palette of living organisms in a Petrie dish. Fleming, it may be argued, is the father of bio art." (Anker, 2014)

As microscopic images show the richness of aesthetic property itself, bio art allows artists to investigate and explore the implications of nature. Artists and scientists work in teams and collaborate to reveal what we can learn from the hidden images. Anker mentioned that ethical issues are the remaining topics (e.g. synthetic biology) We could reveal ourselves, project future, and reorient what is already extant through innovative creations in bio art.

Biometric data such as fingerprint, iris, and DNA has microscopic images, which create aesthetically richer and highly detailed results when they are magnified. Most of bio artworks using biometric data have good engagements with the audience due to their magnified visual results, which turn unexpectedly beautiful outcome in terms of its patterns, colors and visual structures. It also reveals the hidden narratives of human body and genetics, and even synthesizes multiple aspects of biological traits to create newer results. All of these aspects lead powerful results in the art installations. The transformation from nano-scale into visible-scale image/sound also allows the audience to explore diverse observations on the human body, and this idea applies to my research and artwork. More details are discussed in Section 5.6.3.

Chapter 3

Biometric Data Visualization and Sonification

This chapter will discuss how biometric data is analyzed and applied in visualization and sonification. Since biometric data visualization and sonification are rare in art practices, the scope of this discussion encompasses a broad range of data related to the body rather than being limited to only biometric data. Moreover, greater focus will be placed on data sonification in this chapter, as it is the key method of applying biometric data in this research. As biometric data is rarely used as an artistic medium, both technical investigations and meaningful stories about biometric data will be described.

3.1. Biometric Data

Biometric identifiers are the distinctive, measurable characteristics used to label and describe individuals. (Jain, 2008) Examples include fingerprint, palm veins, face recognition, DNA, palm print, hand geometry, iris recognition, retina and odor/scent. Behavioral characteristics are also recently new types of biometrics such as movement of a person, handwriting, gait, typing rhythm, and voice.

Due to the privacy and identification issue, a variety of applications and techniques of biometrics has been developed in a fast pace in the modern time.

Biometrics have been controversial as it would dehumanize the person by turning the human subject into a collection of biometric parameters and losing human dignity. An Italian philosopher Giorgio Agamben refused to enter the United States in protest at the United States Visitor and Immigrant Status Indicator (US-VISIT) program due to its requirement for visitors to be fingerprinted and photographed. (Agamben, 1998) According to Agamben, biometrics turns the human persona into a bare body. Agamben uses two words, life and bios; "life" refers the life of animals and humans as described literally, and "bios" refers the life in the human context, with meaning and purposes. He anticipates the possible scenario of losing the whole humanity through using and collecting the biometrics. For him, a new relationship between citizens and the nations would change the citizens into the "life" instead of "bios" by losing dignity and humanity; and biometrics would be used to start this new world. (Agamben, 1998) Biometrics has been regarded as a secure identification however it may standardize measurements of specific body parts and generate possibility of failure. Shoshana Amielle Magnet argued the possible failure of biometrics using a case of identification of Asian women. According to her, the biometric system often fails to recognize the age, gender and race of Asian women with their hands and eyes due to the template is decided for white, heterosexual, and male. She concludes, "Human bodies are not biometrifiable.” (Magnet, 2011) Kelly Gates also explains that the dual aim of facial recognition technologies is to “automate the mediated process of connecting faces to identities, and to enable the distribution of those identities across computer networks” in order to enhance search ability of individuals in vast populations. (Gates, 2011) Therefore, biometrics changes what identity means to society, governments and its institutions, and produces new identities and categorizations.

3.2. Biometric Data Visualization and Sonification

This section will discuss biometric data visualization and sonification.

3.2.1. Biometric Data Visualization

In the fields of biometric science and related area, one of the most challenging parts in the visualization techniques is to visualize complex and large image data of biometrics. Current research shows several approaches for visualization techniques. Table 3.2.1 shows the four types of visualization techniques and its characteristics. (Holder, Robinson and Laub, 2011)

Table 3.2.1: Types of Visualization Techniques and Its Characteristics (Holder, Robinson and Laub, 2011)

Type of Visualization Technique	Descriptions
Pixel-Oriented Visualization Technique	The process of image features extractions at a pixel level which belonging to the visual components.
Geometric Projection Visualization Techniques	It finds informative transformations of multidimentional datasets, which support a multi-scale data representation technique. It is useful for a variety of application such as data compression, interpretation.
Icon-Based Visualization Techniques	A method of mapping each multidimentional data item to an icon, which is more specific approach and the visual features vary depending on the data attribute values
Hierarchical Visualization Techniques	It subdivide the data space and present subspaces in a vertical fashion, which the image attributes are treated differently with diverse views of the underlying data.

3.2.2. Data Sonification

Another topic in this dissertation is *data sonification*, which is a technically crucial aspect of both the implementation and development of the framework. This chapter discusses the background knowledge necessary to understanding body data sonification and prior works in the field.

Sonification is the transformation of data relations into perceived relations in an acoustic signal for the purpose of facilitating communication or interpretation. (Hermann, 2011) Sonification seeks to translate data or information into sounds that exploit the auditory perceptual abilities of human beings. It is a relatively new term, and a complete definition and theoretical paradigm have yet to be articulated. However, many sound artists, designers, researchers, and engineers have explored a number of approaches and methodologies that have advanced the field.

According to Thomas Hermman (Hermann, 2011), there are five functions of sonification: alerting functions, status and progress indication, data exploration, entertainment, and art. Compared to the other four functions, which mainly investigate the purpose of information delivery, sonification in art explores aesthetic meanings in a subtle distinction between sonification and music. In this dissertation, sonification refers to a way of transforming visuals and data into audio not only to facilitate understanding data but also to pursue meaningful art practices. Two different approaches to sonification can be applied depending on the characteristics of the data: 1) parameter mapping sonification, and 2) model-based sonification. Parameter mapping sonification links changes in some data dimensions with changes in an acoustic dimension to produce the sonification. The data must be constrained, and a lower dimension display is preferred. Typically, the passive mode of interaction is used. In contrast, model-based sonification requires a virtual model that is driven by the data-driven model's reactions to the actions of the user. (Hermann, 2011) The user can actively manipulate the sonification to change and control the results with higher data dimensionality and large numbers of data points. The process of designing sonification requires active feedback between the system and users. Murray Schafer states, "Impression is only half of perception. The other half is expression." (Schafer, 1977) This suggests that sonic acting is as important as listening. Close-loop interaction will enhance listeners' engagement of sonification artworks, and the interface will be easier to use based on the user's feedback. In "Random Access" by Nam Jun Paik (1963), visitors could generate sounds by moving the audio recorder head over the audiotapes arranged in abstract shapes on the wall. The rearrangement of a technological device offered the visitors a rich sonic experience through their direct engagement with sound material. The unpredictability of visitors' gestures created sounds that the artist could not compose or predict. Abandoning the traditional role of the audience as a listener or spectator meant that the artist was giving up control by making the ability to manipulate his artifact accessible to all. Today, audience engagement is an integral part of many sound installations as well as social and participatory media projects. As Murray Schafer suggests, the awareness of our sonic contributions may be the key to reshaping the quality of our experience.

3.2.3. Static Body Data and Dynamic Body Data

Among the many datasets available for sonification, body data is a popular dataset in many different fields. Sonification is commonly used to enhance the readability of complex datasets in medical research, engineering research, and even art applications. There are two kinds of body data: static body data (unchanging data such as DNA, skin patterns, irises, fingerprints, body contours, etc.) and dynamic body data (constantly changing data such as facial expressions, body gestures, EEG (electro encephalography), blood pressure, or body temperature). Dynamic body data has been explored in many kinds of research, frameworks, and artworks. One of the best examples involves tracking participants' body movements with a camera and using their contours, silhouettes, or shadows to produce a sonic response so that the participants can instantly understand how to create new results by exploring different movements. However, in my research, the dynamic data is changing, non-stable, and non-indexical. Participants can create similar results, and the system doesn't recognize each participant's identity. In order to create varied and personalized art experiences, I chose to use static body data instead of dynamic body data. However, the use of static body data doesn't mean that only a small number of data features will be explored in my research. Static body data is often misunderstood by the public; many people believe that it is a single, unique identifier. For example, DNA contains complex banding patterns in an unchanging, infinitely long sentence generated by genetics that corresponds to each living creature. Fingerprints also contain various hidden visual features in the lines, composed of ridges and valleys – the so-called "minutiae". Thus, static body data not only indicates the individual's identity, but also includes multi-dimensional layers of datasets in a single data pattern. Comparisons between the static body data and dynamic body data are summarized in Table 3.2.2.

Table 3.2.2: Comparisons between Static Body Data and Dynamic Body Data

	Static Body Data	Dynamic Body Data
Type of Input Data	Static images, multi-dimensional data	Consistently changing images/data, multi-dimensional data
Changes	Non-changing (original data)	Changing over time
Examples	DNA, skin patterns, irises, fingerprints, body contours	facial expressions, body gestures, EEG (electro encephalography), blood pressure, or body temperature
Techniques and Analytic tools	Image scanning, biometric data technology	Camera sensing technology, Electronic Data Signal Technique

Sound is everywhere. Even though visual information delivers the higher impact on our memory, auditory data plays a critical role in understanding and capturing our experience and information. The auditory data contains important narratives based on timeline since it reverberates our bodies to fully experience everything surrounding us every moment. Furthermore, many factors control aspects of the auditory data: recording direction, location, time, environment, recording duration, and so on. It can be changeable, diversely manipulated and improvised. Auditory data is hard to predict and it all depends on how we capture and listen the improvised data. Every seconds, we produce and experience diverse auditory data. And the data can reveal our individual relationships with environment and others, and understand new knowledge on ourselves. On top of the visual element, sonic data will give a higher impact on both readability and sensibility that can reverberate the audience. In order to efficiently read the static body data, the sound is a key part to unlock the complicated information and visual patterns. The common purpose of body data sonification is to enhance the readability of the data, and enable users to explore and teach the data to develop a better interface. Prior work and research on body data sonification will be described in the next section.

3.2.4. Prior Works – Related Body Data Sonification

There are many examples of sonification of other kinds of body data or body patterns, which influenced my research. Worgan sonified faces using multiple sound synthesis techniques such as additive methods, wave terrain, and frequency modulation to represent facial data, which is the visual focal point in person-to-person interaction. (Worgan, 2005) Although the mapping of each facial feature (eye, mouth, eye color, face color, etc.) in this research is novel, the mapping is not highly effective in delivering visual data. It is very difficult to make conclusions about the effectiveness of any form of mapping without conducting extensive user studies. Mapping should describe not only the differences between faces but also deliver the appropriate sound psychologically. This issue is usually the most challenging part of sonification, and this paper has led to a more in-depth consideration of the mapping method of sonification. Daito Manabe created "Face Visualizer," (see Figure 3.2.1, right) which controls music with facial expressions. (Manabe) Electrical sensors attached to the surface of the face detect the electrical pulses that control muscle movements. His work directly transformed the body into sound and made it possible to create a live music performance in real time, which was highly beneficial. The real-time performance aspect of this work influenced the work described in this dissertation.

Although most examples of body data sonification involve sonified body movements or dynamic gestures sonified over time, there are also examples of sonifying internal or invisible body data, such as brain activity (e.g., brainwaves, biorhythm, emotions, or sleep). In "Music for Solo Performer" by Alvin Lucier, EEG and Alpha state brain wave data is amplified in order to control musical instruments. (Lucier) (see Figure 3.2.1, left) The electronic signal generated by the unconscious control of the performer (Alvin Lucier himself) transforms the data into virtual excitation to play drums in front of the performer. The amplifier is a powerful device, which gives access to invisible body data to empower action and control in a real-time musical performance. Whereas the performer's control in the brain is mirrored by the action of hitting the drums with sticks, in this work the performer visualizes imagery to maintain a 10-Hz alpha state without any physical body movements apart from blinking.

This new way of mirroring ourselves throughout the thought processes of the brain creates new possibilities of expressing ourselves as sensible individuals. The subtle choices and manipulation of brain processes create enormous differences in the sonic variations. Weinberg and Thatcher developed the sonification of neural activity in their projects titled "Fish and Chips" and "Brain Waves". (Weinberg and Thatcher, 2006) Angel also applied an artistic approach to the transformation of brainwave data. In her installation and performance, EMG (electromyography) and EEG are used to explore the interaction between the human body and real-time media. (Angel, 2011) Brainwaves result in dynamic datasets and invite interactive sonification. Olga Sourina studied human-computer interfaces that are based on brain state recognition from the EEG, and proposed a fractal-based approach to the recognition of brain states including emotional recognition and concentration level recognition. (Sourina, Liu, Wang and Nguyen, 2011) This allowed the user to have a more personalized experience during the human-computer interaction.

Figure 3.2.1: (Left) *Music for Solo Performer*, Alvin Lucier, 1965[vi]
(Right) *Face Visualizer*, Daito Manabe, 2008.[vii]

3.3. Biometric Data Visualization and Sonification as Art Forms

Biometric technologies have been highly controversial in these days by raising many questions and concerns. In order to enhance search ability and technical development of identification, there has been on-going research on investigating new ways of developing biometric technologies in many disciplines. Furthermore, biometrics do fail in numerous ways according to following opinions. The biometric failure is not only because of the issues in technical developments, but also involvements of cultural and societal issues. As Shoshana Amielle Magnet and other researchers mentioned, biometric failure reveals a rigid classification system that works against minoritarian populations. (Magnet, 2011) To investigate these issues, multimodality may be a posilibity of expand and enhance the readability of the biometrics. Artistic approaches on revealing the narratives beyond the visualizing and sonifying the biometric data using both existing and new techniques might give potential answers on the biometric failures and also points out the current issues of the biometric technologies in the society these days. As other biometric data artworks such as Zach Blas' facial weapon attempt, biometric data artworks can examine the current biometric technology, protest against the biometric use for the identification, or suggest a possibility of re-considering the issue for the audience.

Chapter 4

Previous Practice

In this chapter, my previous practices on creating various interactive artworks with related topics will be discussed. The practices not only explore various artistic experiments and methodologies on related topics such as biological art, data visualization and sonification, but also show how they lead to develop the objectives and goals of this research. Those related topics have been critical parts of development of final artworks in both context and technical aspects in conjunction between art and technology. Most of these works have been exhibited and published in various art exhibitions and conferences. Brief descriptions, technical implementations, and results with images and lists of published achievements are provided.

4.1. Biological Art

4.1.1. One

Completed year: 2009

Type: Interactive Biological art Installation, interactive art installation

Collaborators: Erick Oh and Gautam Rangan

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'One' tries to immerse the viewer in fantasy through animation. The audience is presented with a small dish that contains a little spilled ink - what happens inside and around this drop of pigment? If you look close enough, you can see that the ink is listening. The viewer assumes the role of a god; tapping, prodding, covering, blowing on and speaking to the ink induces complex and intricate responses. The microcosm that evolves from doodling both reflects and subverts the natural systems in which we live. The shapes that emerge are similar to shapes in plants, animals, and bacteria, but they avoid representation- they contest the work of biologists like Antonie van Leeuwen Hoek and Ernst Haeckel. This art installation tries to communicate the way we struggle with the natural world, trying to imagine something better and eventually conceding to failure. Our fate is a cause and effect of today's design environment. We create within in a vast network of programmers, researchers, theorists and artists who craft tools as indispensable structures for production. Working with graphics and rendering technologies provides immediate access to a communally developed visual language and encourages us to act as members of this community. This work is my very first approach to explore the biological art with media technology. It investigates how spectators' interactions impact the life of artificial creatures, which becomes inspirations and motivations for the current research.

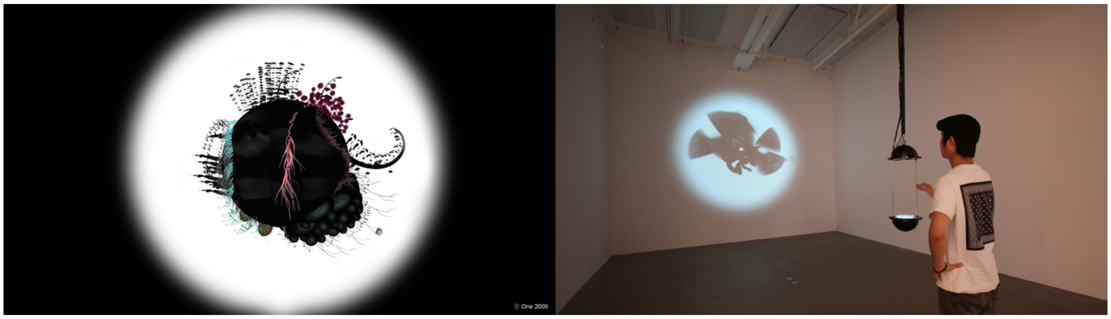

Figure 4.1.1: *One*, Yoon Chung Han, Erick Oh and Gautam Rangan, 2009

Publication:

Yoon Chung Han, "One" BioLogic: A Natural History of Digital Life, ACM Leonardo Journal Vol.42, No.4, pp.372-373, 2009

Exhibitions:

12.2009 "Are We Human?" Inspace, The University of Edinburgh, United Kingdom.

10.2009 AFK(Away From Keyboard) UCLA Design | Media arts 2nd MFA Grad Exhibition, New Wight Gallery, Broad Art Center, UCLA, USA

09.2009 Collider: Interactivity and New Media, The Emily Davis Gallery, Myers School of Art, The University of Akron, 150 East, Exchange St. Akron, OH. USA.

09.2009 The Fragments of Sound - 1st Solo Exhibition, Artspace-hyun, South Korea

08.2009 "ACM SIGGRAPH 2009 Art Gallery, Ernest N. Morial Convention Center, New Orleans, USA

08.2009 Videotage - Yoon Chung Han's selected works with Erick Oh's animation, Videotage, Cattle Depot Artist Village, Kowloon, Hong Kong

Awards:

02.2010 13th Japan Media Arts Festival, The National Art Center, Tokyo. Jury Recommended Work

08.2009 Adobe Digital Art Award (ADAA), Semi-Finalist in Installation Design "One"

4.1.2. Digiti Sonus V1

Completed year: 2012-13

Type: Interactive Fingerprint Sonification, Interactive art installation

Collaborator: Byeong-jun Han

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This work is the fundamental approach and practice of the current research. This first version of Digiti Sonus is an interactive audio/visual art installation based on fingerprint sonification. Transforming fingerprints' unique patterns into sonic results allows the audience to experience the discovery of sensory identities. The sonification of data produces a real-time music composition as a representation of integrated human identities. The distinct visual features of fingerprints as an open musical score are executed in diverse ways and converted into three-dimensional animated images. By varying the starting point of animated visuals, the musical notes are reorganized in different orders and duration, and they resonate in listeners' bodies and minds. More detailed technical implementations will be described in the next chapter. This work was supported by DaVinci program from Geumcheon Art Space in Seoul, Korea in 2012.

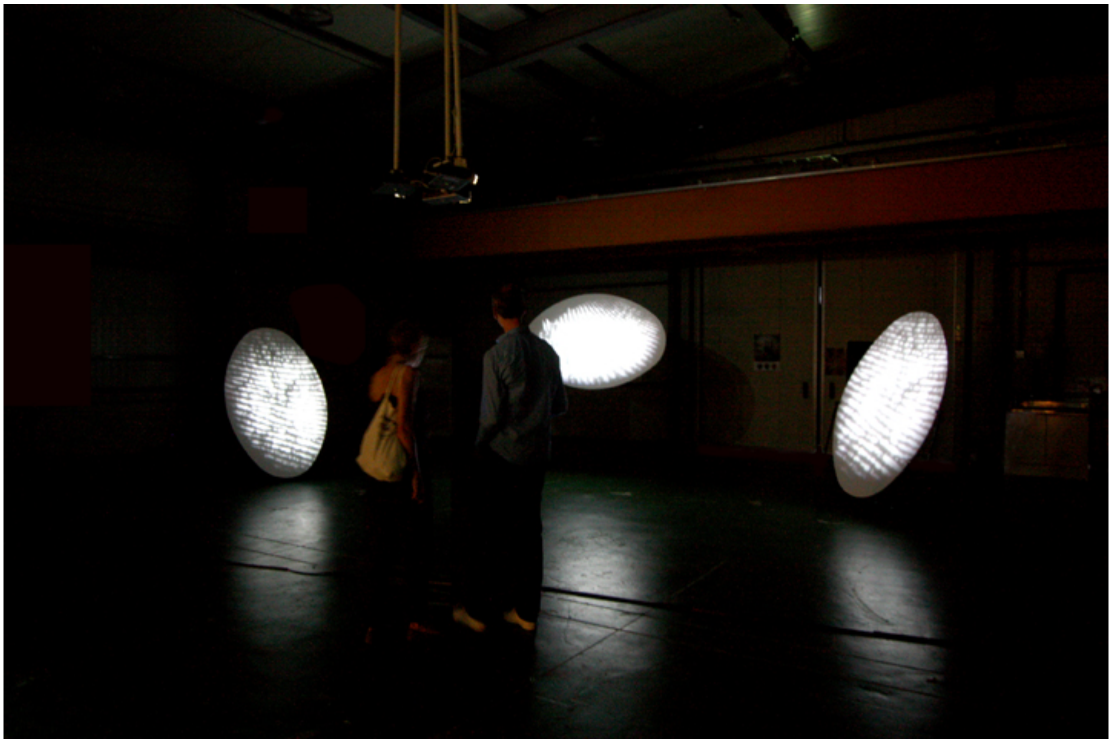

Figure 4.1.2: *Digiti Sonus*, Yoon Chung Han and Byeong-jun Han, 2012-2013. An Exhibition View at the Geumcheon Art Space in 2013.

Publications:

Han, Yoon Chung and Byeong-jun Han, "Digiti Sonus" XYZN: Scale, ACM Leonardo Journal Vol. 46, No.4, July 2013.

Han, Yoon Chung, Byeong-jun Han and Matthew Wright. M. "Digiti Sonus: Advanced Interactive Fingerprint Sonification Using Visual Feature Analysis," Proceedings of New Interfaces for Musical Expression (NIME). 2013. (Full Paper)

Han, Yoon Chung and Byeong-jun Han, "Digiti Sonus: An Interactive Fingerprint Sonification," ACM Multimedia 2012.

Exhibitions:

10.2015 L.A.S.T Festival, Stanford University, CA USA

09.2015 ZKM GLOBALE: Infosphere exhibition, ZKM, Karlsruhe, Germany

10.2014 "Hybrid Highlights," Museum of Art, Seoul National University, Seoul, Korea

08.2014 "Sonic Trace" The Second Solo Exhibition (supported by AliceOn), The Medium, Seoul, Korea

02.2014 "Daily Reflections" at Total Museum, Seoul, Korea
07.2013 ACM SIGGRAPH 2013 Art Gallery, Anaheim Convention Center, Anaheim, CA,USA
05.2013 MAT End of Year Show 2013, Elings Hall, UCSB, USA
11.2012 Seoul Mecenat and ArtsWalk 2012, Seoul, Korea
09.2012 Media City Seoul 2012 DaVinci Exhibition, Geumcheon Art Space, Seoul, Korea

Awards:

12.2012 Asia Digital Art Award (ADAA) 2012 - Finalist Award
05.2012 DaVinci Media Art Competition 2012 from Seoul Art Space – Selected artist

4.1.3. Skin Pattern Sonification

Completed year: 2014

Type: Data Sonification

Collaborator: Byeong-jun Han

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This project explores the use of sonification to represent the scanned image data of skin pattern of the human body. Skin Patterns have different characteristics and visual features depending on the positions and conditions of the skin on the human body. The visual features are extracted and analyzed for sonification in order to broaden the dimensions of data representation and to explore the diversity of sound in each human body. Non-negative matrix factorization

(NMF) is employed to parameterize skin pattern images, and the represented visual parameters are connected to sound parameters through support vector regression (SVR). The sound results are compared with the data from the skin pattern analysis to examine how much each individual skin patterns are effectively mapped to create accurate sonification results. Thus, the use of sonification in this research suggests a novel approach to parameter mapping sonification by designing personal sonic instruments that use the entire human body as data. More detailed analysis and challenges will be discussed in the Section 5.5.

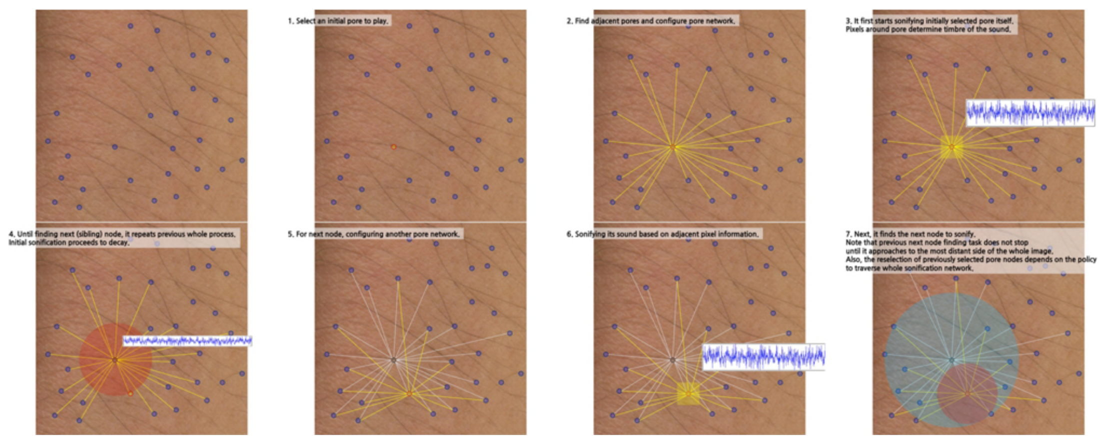


Figure 4.1.3: "Skin Patten Sonification": An Example on Configuration of Pore Network on Skin Pattern. Image reprinted with permission.

Publications:

Han, Yoon Chung and Byeong-jun Han, "Skin Pattern Sonification as a New Timbral Expression," Leonardo Music Journal Vol. 24, December 2014.

Han, Yoon Chung and Byeong-jun Han, "Skin Pattern Sonification Using NMF-based Visual Feature Extraction and Learning based PMSon", International Conference for Audio Display (ICAD) 2014, June 2014.

4.2. Data Visualization and Sonification

4.2.1. Seattle Public Library Data Visualization

Completed year: 2012-2013

Type: Data Visualization

This study is to explore various ways of visualizing data and how to read meaningful stories and relations with culture and society in data. A series of this study uses data from the Seattle Public Library database acquired through George Legrady's "Making Visible the Invisible" artwork (Legrady, 2005), a permanent art commission that receives approximately 30000 data records per day representing books, CDs and DVDs checked-out by library patrons. The project began in September 2005 and will be operational until 2019. There are at this time over 70 million recorded transactions available that can be studied in detail to map how topics of interest to the patrons have changed overtime during the past decade.

Earth

The main goal of this project was to explore total transactions between 2005-2011 related to "Earth." The query searched the whole transactions that had more than 20,000hours (833days, 2.28years) checked out duration. The book contents included "Earth" in titles or keywords.

The overall visuals looked like a 3D sphere or Earth. Each different color represented different Dewey classes. There are two parts of designs: first one is based on 3D sphere structure. Second one is a text sphere. Based on timely spiral shape, small spheres were situated from top to bottom, and the radii of spheres represented the duration of transactions. And the lines across the spheres connected each checked out and in items with the same Dewey colors. You can see only spheres, or lines by pressing key 1,2,3. Also, each year, month, day date and duration numbers show up next to each spheres when you press key 4. Finally, all the book titles are shown up from the center, and spread toward to outside. (key 5)

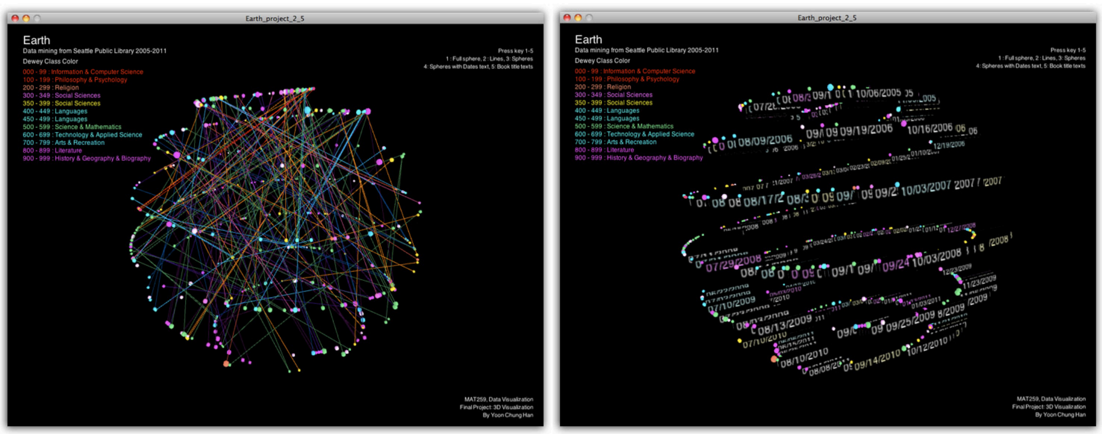


Figure 4.2.1: Screenshots of "Earth" Data Visualization, Yoon Chung Han, 2012.

Seattle Musicians

Seattle is a city rich in a music history supporting a thriving industry that is renowned nationally and globally. In this project, I will explore how much Seattle people love a classical music and how many items related to the best 13 classical musicians they checked out from 2005 to 2010 at SPL.

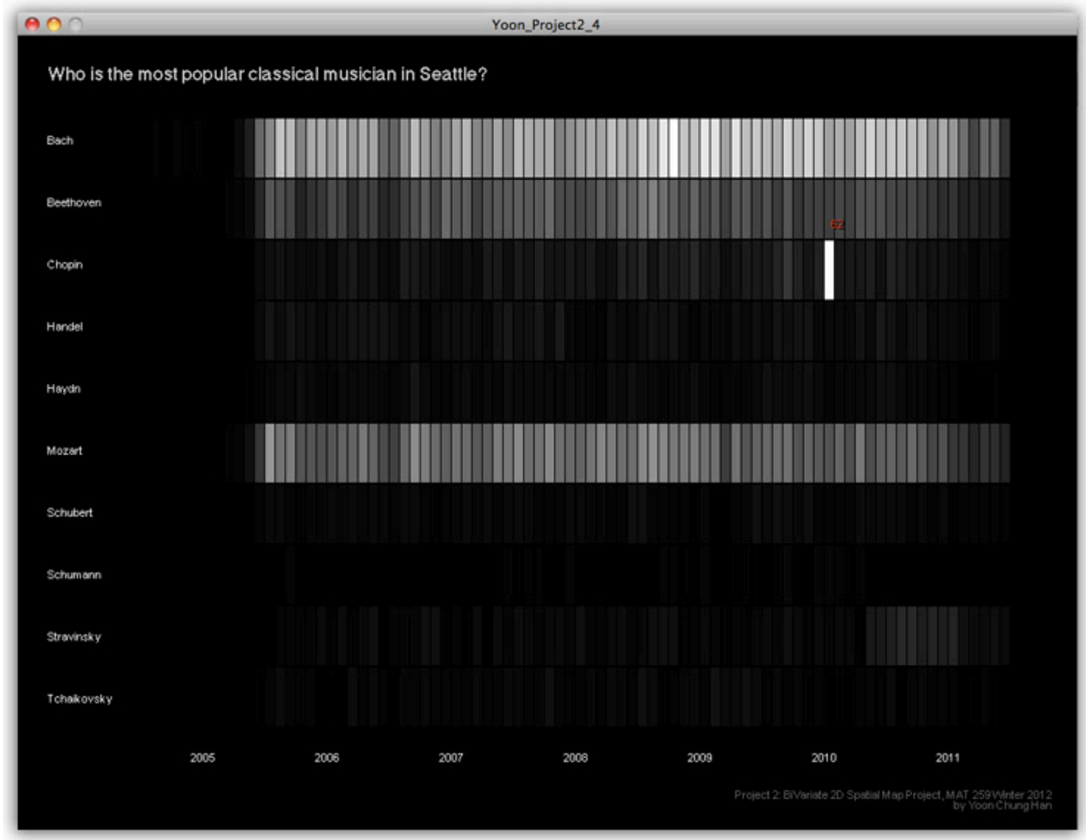


Figure 4.2.2: Data Visualization about the most popular classical musicians in Seattle, Yoon Chung Han, 2012.

In a visualization graph, left side will show the visualization of data of checked out items each year and months. On the right side, there will be a list of 13 musicians vertically, and each musician's data can be explored by clicking a small checkbox. Each musician will be determined by different colors as a line, and users can select which musician they want to see or compare with other musicians. X axis in the graph will represent time (months and years), and Y axis will represent the number of checked-out items. In the X, Y cross position, there will be a small square with a given color based on musician's name, and the square will be connected together with a light line. There will be a smooth animation that delivers a feeling of music equalizer.

North + South Korea

The goal of this project was to investigate how many items related to North Korea and South Korea checked out from 2005 to 2011. And I was also interested in different results between NY Times and Seattle Public Library since NY Times is based on newspaper and online articles, and Seattle Public Library contains many different kinds of mediums and contents. I was curious how much items people checked out, and how it would be related to each other over years. In this data visualization, I mostly focused on color contrast: Red as North Korea and Blue as South Korea. The two color represent the national colors in national flags, and it directly shows the two countries' different identities. Through this research, I was surprised that there were quite many items checked out over years, and NY Times and SPL showed different peak times.

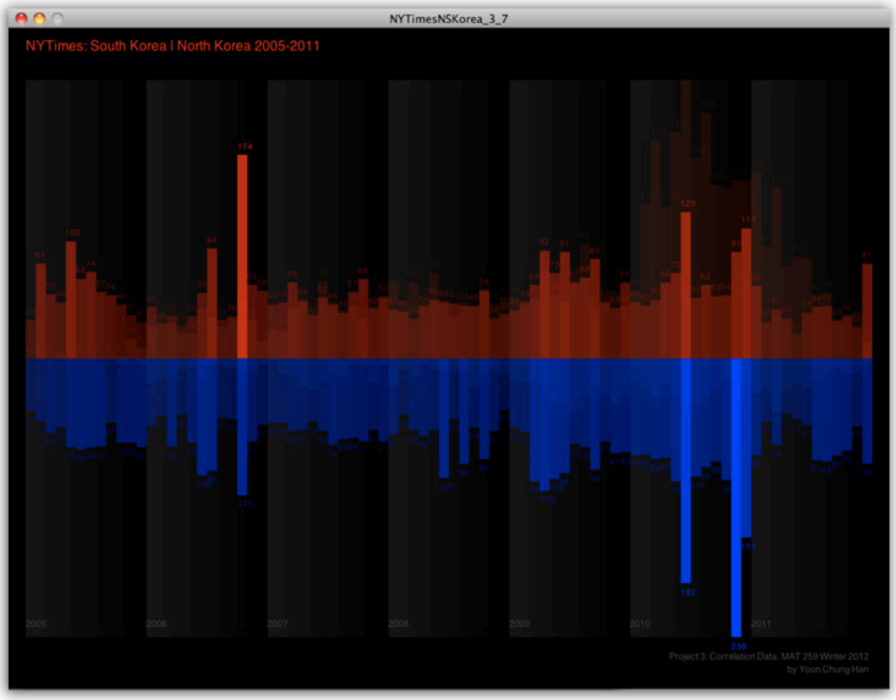


Figure 4.2.3: Data Visualization on North + South Korea, Yoon Chung Han, 2012

2D spatial map

I wrote to show the ranks of the Dewey classes in each hour and modified it so that you can look across each row (Dewey category) and see how it's rank changes based on the brightness of the squares and HSV colors. You can see for example that Dewey class 789 falls in rank at 8 and 9 am and also see how much the ranks fluctuate for each class based on the difference in brightness. Also you can look at the vertical columns to see how the categories compare in rank to each other.

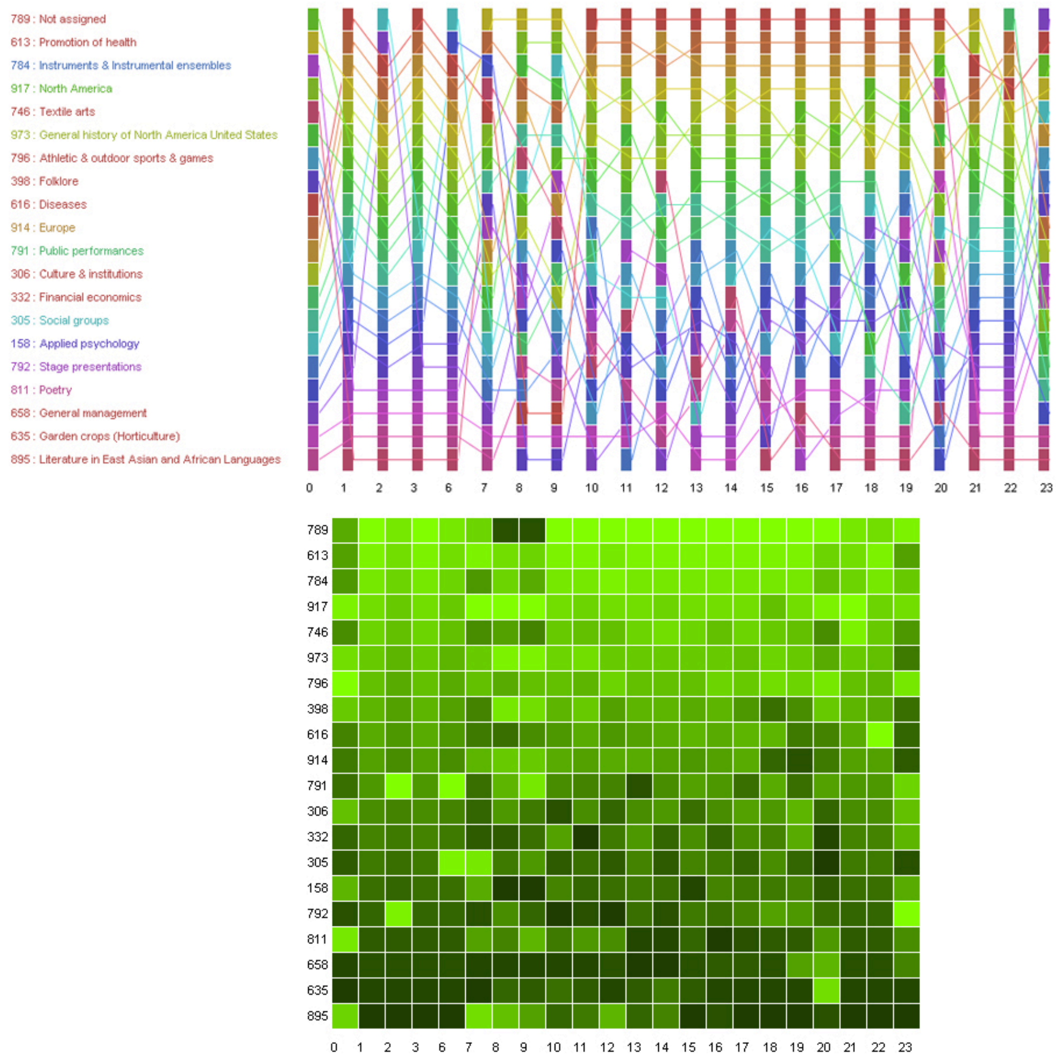


Figure 4.2.4: ***2D Spatial Map*****, Yoon Chung Han, 2012**

4.2.2. Cloud Bridge

Completed year: 2012-2013

Type: Data Visualization and Sonification

Collaborator: Qian Liu

Cloud Bridge explores how data can be visualized and sonified to facilitate findings, understand and analyze information by using multi-dimensional representation in an innovative way. It visualizes and sonifies data from a set of check-out records from a rich collection of data accessed through the artwork "Making Visible the Invisible" by the artist George Legrady at the Seattle Public Library. (Legrady, 2005) Therefore, Cloud Bridge opens up the possibility of scaling among different mediums: from traditional prints, desktop/laptop displays, to gallery-style installations with mobile device interaction, and even large-scale immersive stereoscopic environments.

As a multi-dimensional installation, Cloud Bridge not only scales the historical data into a XYZn dimension, but also sonifies it for resonating our bodies. This immersive artwork focuses on encouraging users to dynamically query the dataset to generate audio visualizations based on their data choices, exploring the history of item transactions from different perspectives. Users can query the database by typing keyword through iOS devices, and receive related items' history. The results retrieved from each user are visualized and sonified in each designated color.

Cloud Bridge is an interactive audiovisual artwork using library transaction data, which represents a novel combination of data sonification, data visualization, and multi-user interaction. The sonification enhances the understanding of query results along with visualization in a large-scale immersive environment, the AlloSphere[3]. The use of dynamic queries in real-time allows users to explore the diverse dataset, and to create a musical conversation. Participants are no longer restricted to a one-way communication, but able to interact with data, in an immersive audiovisual environment, and contribute to new query results expressed in a multimodal experience. User input consists solely of entering query text and choosing when to trigger the beginning of the unfolding of the audiovisual response to the query, enabling a performance practice more akin to interactive data mining. The content of the database defines the bounds of this unique instrument by determining all potential results, from which potentially many simultaneous users can select possibilities. Users can approach Cloud Bridge as a sonification tool for exploring patterns in the database, as an improvisatory, interactive audiovisual artwork, or by thinking in terms of linguistics such as by choosing keywords to form sentences and larger narratives, perhaps by creating a "tone poem" or a "play on words." Another major challenge that Cloud Bridge attempts to address is to create an interactive audiovisual interface that works equally well regardless of venue, from laptops/desktops, to gallery-style installations with mobile device interaction, and even large-scale immersive stereoscopic environments such as the AlloSphere.

[3] The AlloSphere is a 3-story high spherical space located at the University of California, Santa Barbara. It serves as an advanced research instrument in which fully immersive, interactive, stereoscopic/pluriphonic virtual environments can be experienced, enabling works in which art and science contribute equally. Joann Kuchera-Morin is the director of the AlloSphere and its original inventor.http://www.allosphere.ucsb.edu/

Future work includes exploring other synthesis techniques and sonification methods including additive synthesis, IFFT synthesis and dynamic filters, looking for a greater variety of sound timbres. It may be beneficial to map the change infrequency over the arcs and use the z-axis as a spatial distance axis. The work could also take greater advantage of the AlloSphere's multichannel spatial sound system. Another important consideration is the need to normalize the data with the current sound representation since longer check-out times result in higher peak amplitudes. Future interaction research will encompass adding more query techniques. This will facilitate building out the software infrastructure as a general-purpose data-driven multimodal instrument.

Publications:

Han, Yoon Chung, Qian Liu, Joanne Kuchera-Morin, Matthew Wright, and George Legrady, "Cloud Bridge: a Data-driven Immersive Audio-Visual Software Interface," Proceedings of New Interfaces of Musical Expression (NIME). 2013.

Exhibitions:

02.2014 "Digital Media" at Cal Poly San Luis Obispo, San Luis Obispo, CA USA
05.2013 MAT End of Year Show 2013, Elings Hall, UCSB, USA

Figure 4.2.5: *Cloud Bridge*, Yoon Chung Han and Qian Liu, 2013, (Left) Cloud Bridge in AlloSphere (Right) Prints at MAT End of Year Show 2013

4.2.3. Art Traffic at the Louvre[4]

Completed year: 2014

Type: Data Visualization

Project website: http://senseable.mit.edu/louvre/

Director: Prof. Carlo Ratti

Team: Yuji Yoshimura, Stanislav Sobolevsky, Stefan Seer, Pierrick Thébault and Matthew Claudel

Data Holders: Yuji Yoshimura and the Department of Visitors Studies at the Louvre Museum

In collaboration with data scientists and researchers at SENSEable City Lab in the Massachusetts Institute of Technology, the project "Art Traffic at the Louvre" explored how visitors move through a museum like the Louvre in Paris – what galleries they visit, what path they take, and how long they spend in

[4] Please visit the project website for more detailed credit for this project. http://senseable.mit.edu/louvre/

front of each piece of artwork. The research team deployed seven Bluetooth sensors, with sufficient coverage to measure visiting sequences and duration at key representative locations. (the entrance, two key locations on the floor -1, five key locations on floor 0, and three locations on floor 1) The sensors recorded a unique encrypted identifier that distinguishes each Bluetooth-enabled mobile device within its range, as well as time stamps for entry and exit times. Assuming that a mobile device belongs to a person, we can relate the movement of the device to that of the visitor. The study was conducted over a 24-day period with a high volume of visitor traffic. During this period, the array of sensors recorded the presence of 24,452 unique devices. A data cleaning process has removed security and museum staff traces by matching recurrence with the time of presence (e.g., outsider visiting time). Throughout the 3D data visualization and simulated animation generated by me and other designers, the team could extrapolate visiting sequences and dwell times at key representative locations for the whole number of visitors. These data sets were integrated into microscopic crowd simulations, which allow users to examine visitors' movement behavior in greater detail. This simulation-based prediction and analysis of visitor flows reveals valuable information such as crowd density, local congestions and capacity estimations.

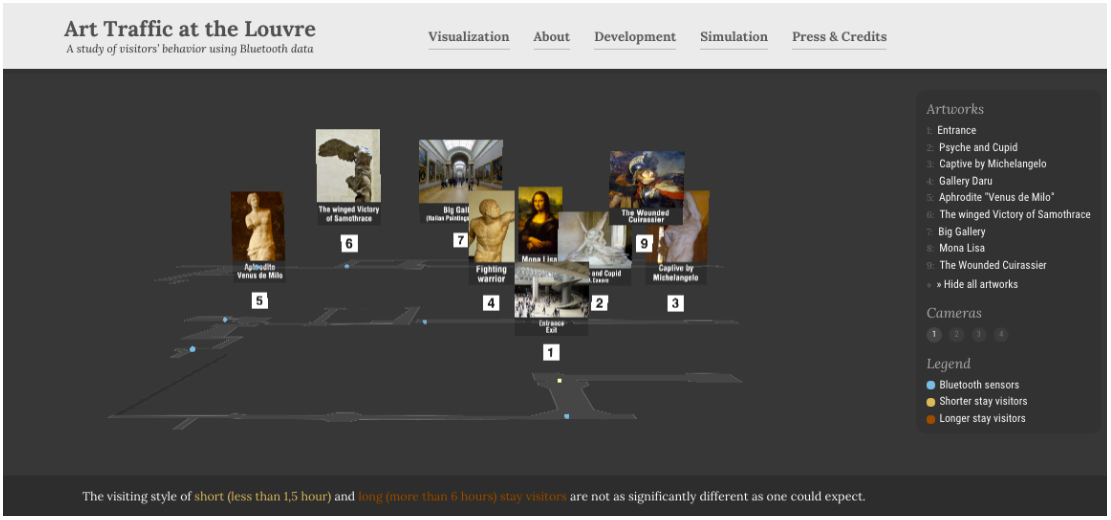


Figure 4.2.6: A screenshot of Art Traffic at the Louvre (MIT SENSEable City Lab)

4.3. Interactivity, Audience Participation and Personalization

4.3.1. Tree Rings and Sound Tree Rings

Completed year: 2012-2013

Type: Sound Visualization and iOS Application

Collaborator: Nuribom, Seoul, South Korea

"Tree Rings" explores sound's organic essence by visualizing its time dimension as a spiral series of tree rings, modulated by urban soundscape transcribed to waveforms. This piece highlights the natural harmonic beauty of sound - when used outdoors, the sounds of our renovated urban cityscape can be used to regenerate a relic of the natural landscape that was destroyed so that it could exist. By showing our individual and societal voices and sounds in tree ring form, we stay true to the spirit of the rings, preserving the imagery for a more modern age.

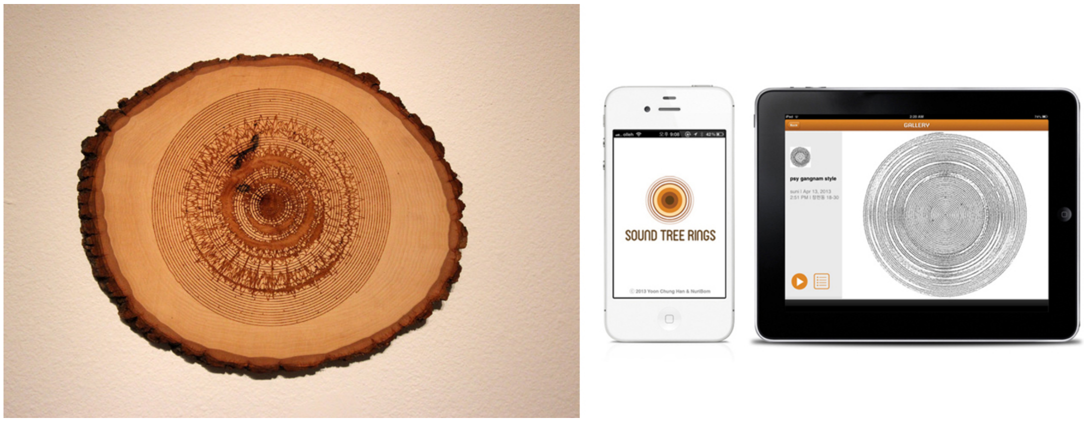


Figure 4.3.1: (Left) *Tree Rings*, Yoon Chung Han, 2012 (Right) *Sound Tree Rings* - iOS App in collaboration with Nuribom[viii], Yoon Chung Han, 2013.

"Tree rings" contain real trees' narratives - their history, time and space in spiral timeline shapes. Trees provide beauty and inspiration, they help free oxygen to keep us breathing, yet we destroy them for our benefit regularly, using their body parts for housing, cardboard, even for temporary data storage needs. Trees invented the first 'ring memory,' many thousands of years before humans discovered electricity.

Sound Tree Rings is an iOS application and print/lasercut artwork service. Users can download this app, record their own sound, and capture their short moment of sound experience. Finally the sound result can be saved and print out on papers or woods.

This is very first idea that connected the relationship between sound and tree ring memory in both artist and public ways, which makes this project as a leading and innovative project. Sound Tree Rings is very new type of interactive artwork and service, and everyone can make and share their own sound stories with this app.

Exhibitions:

04.2013 "Things That Turn Your Brains To Mush", Santa Barbara Contemporary Arts Forum Santa Barbara, CA, USA

05.2012 MAT End of Year Show 2012, Elings Hall, UCSB, USA

01.2012 "Tree Rings" A Solo exhibition in gallery 479, UCSB, USA

4.3.2. Virtual Pottery

Completed year: 2012-2013

Type: Interactive Audiovisual Installation

Collaborator: Byeong-jun Han

Virtual Pottery is an immersive audiovisual installation that uses hand gestures to create 3D pottery objects and compose real-time sound piece. Using the simple and anagogic metaphor, Virtual Pottery attempts to transform body gesture into digital music domain in a compelling way. The body is transformed into this multi-sensory space as a way of sculpting sound pottery. It delivers the same manner when we do in real pottery creation; sculpting clay, polishing the shape, adding glaze materials, and finally going through the firing process. By using the simple hand gestures, the user can experience this virtual creation and sculpt their own pottery pieces, and compose a real-time music. The meditation feeling, but quite experimental music pushes the user to explore the relation between virtual sculpting and spatial sound composition.

There are three projections in the multi-channel audio and projection room, and three pieces of pottery are projected on each screen. Under the Opti track motion capture (Rigid body) system in TransLab, UCSB, The user is able to take a glove with attached trackers, and get closer to one of projections in order to start sculpting its own sound pottery. Each pottery has different color, texture, and frequency domain so that the user can explore how the diverse audiovisual characteristics can be created into compelling sound sculpting. By moving the hand in different direction, the user can change the volume and speed of sound as well. Finally, the multiple pottery pieces controlled by the body can dominate this spatial sound environment. Carrying multiple sensory depths, the aesthetics of emotional impacts in this piece reverberate to audience's senses.

Overall, Virtual Pottery serves as a bridge between the virtual environment and traditional art practices, with the consequence that it can lead to the cultivation of the deep potential of virtual musical instruments and future art education programs. Virtual Pottery was presented in two exhibitions with two different camera sensing systems, and the results from the audience was successful. There are a lot of features that could be added, such as more diverse music effects and filters, various glaze materials that can be painted on some parts of the entire clay body, etc. Eventually the design and print of the piece in 3D prototyping machine can be exported to compare it with real pottery pieces. An advanced interface with multiple pottery designs and integrated spatial audio system is considered so that users can compose looping music by arranging pottery pieces in different positions.

Also, other body motions and body gestures should be considered as input for various features such as saving design, exporting design, restarting design, or rearranging the position of multiple designs. For easier control, the other hand's motion or gesture is totally necessary to be applied to extend the current application. Future plans are to develop a more advanced version of Virtual Pottery for artistic experiments, educational content, and extended pottery art application. This interface can be useful for novice users who have not experienced pottery creation before, and it can possibly suggest a good educational heuristic to teach pottery processes and allow users to export their design in 3D printing.

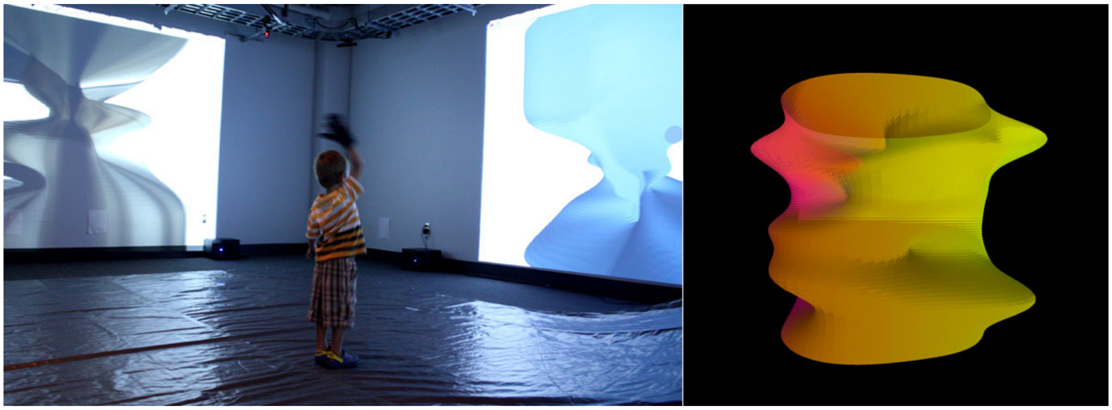


Figure 4.3.2: *Virtual Pottery*, Yoon Chung Han and Byeong-jun Han, 2012-2013. (Left) An Exhibition View at the MAT End of Year Show in 2012 (Right) a screenshot image of Virtual Pottery

Publications:

Han, Yoon Chung and Byeong-jun Han, "Virtual Pottery: A Virtual 3D Audiovisual Interface Using Natural Hand Motions, Multimedia Tools and Applications," Springer Journal. 2013.
Han, Yoon Chung and Byeong-jun Han, "Virtual Pottery: An Interactive Audio-Visual Installation," Proceedings of New Interface of Musical Expression (NIME), Michigan, USA, 2012.

Exhibitions:

09.2014 "Davinci Creative 2014" "Virtual Pottery" Geumcheon Art Space, Seoul, Korea
08.2012 NanoKorea 2012, COEX, Seoul, Korea
05.2012 MAT End of Year Show 2012, Elings Hall, UCSB, USA

Chapter 5

Digiti Sonus: Biometric Data Art using Personalized Narratives and Multimodal Interaction

5.1. Why Fingerprints?

Among all the patterns found in human and primate bodies, fingerprints are the most unique type of visual pattern. They are intuitive and powerful resources that represent the individual's genetic identity. There is no trick or filter in fingerprint patterns. The simple, spiral pattern retains the truth of human birth, genes, and growth. The beginning of human life and the natural naming of the body itself are contained in these simple, tiny patterns at the ends of the fingers. Thus, fingerprints are a great resource for finding societal identities. Fingerprints have been widely used for personal identification. In the digital era, many computer machines and digital interfaces use fingerprints as security keys for identification and to access personal information. However, the overuse of fingerprints has disrupted the rights of personal identities. The superficial, digital identities are saved on a database, and humanity becomes lost in the conversion from biological patterns to digitized societal identities. The question of identification has risen due to digitized personalization based on the personal information designated in society. Artists have tried to find the answer to this question and explore new possibilities regarding our own identities in various ways.

Fingerprints contain genetic information. According to Christophe Champod and Chris J. Lennard, pattern types are often genetically inherited but the individual details that make a fingerprint unique are not. (Champod, Lennard, Margot and Stoilovic 2004) Humans, as well as apes and monkeys, have so-called friction ridge skin (FRS) covering the surfaces of their hands and feet. FRS comprises a series of ridges and furrows that provide friction to aid in grasping and prevent slippage. FRS is unique and permanent – no two individuals (including identical twins) have the exact same FRS arrangement. Moreover, the arrangement of the ridges and features do not change throughout our lifetimes, except in cases when significant damage creates a permanent scar. The term "fingerprint" refers to the FRS on the ends of our fingers.

Fingerprints have a general flow to the ridges that translates into one of the three major pattern types: a whorl, loop or arch. It is possible to have just one, two or three pattern types among your ten fingerprints. It is important to note that an individual cannot be identified from fingerprints by pattern type alone. To identify a person, an examiner must look to the next level of detail: the specific path of ridges and the breaks or forks in the ridges, known as *minutiae*.

(Martoni, Maio, Jain and Prabhakar, 2009) Other identifying features such as creases, incipient ridges and the shapes of the ridge edges are also useful for identification purposes.

The ridges are created in a random process; the spacing and arrangement of the early ridges vary on the overall geometry and topography of the volar pad. The volar pad is a little pillow in the foetal hand, which rise only temporary on the surface of the skin before the permanent manifestation of the dermatoglyphics. (Champod, Lennard, Margot and Stoilovic, 2004) If the primary ridges appear while the volar pad is still quite pronounced (a characteristic described as a "high volar pad"), then the individual will develop a whorl pattern. If the primary ridges appear while the volar pad is less pronounced (dubbed an "intermediate volar pad"), then the individual will develop a loop pattern. Finally, if the primary ridges appear while the volar pad is nearly absorbed, (called a "low volar pad") the individual will develop an arch pattern.

The timing of these two events (volar pad regression and the primary ridge appearance) is genetically linked: genetic timing (inherited from one's mother and father) influences the pattern types. The exact arrangements of the ridges, minutiae and other identifying features, however, are random and not genetically linked (and thus not inheritable). The evidence of this comes from studies of fingerprints from identical twins. Identical twins share the same DNA and, therefore, presumably the same genetic developmental timing. (Tao, Chen, Yang and Tian, 2012) The fingerprints of identical twins often have very similar size and shape pattern types. However, the identifying characteristics are different. This fact demonstrates that you are more likely to share pattern types with your family members than an unrelated individual, but your identifying FRS features will always be unique.[5]

Based on this knowledge of a fingerprint's genetic information and visual features, I use fingerprint data as the primary material in this framework for the following reasons:

1. Fingerprint images can become a main resource used to represent each participant and create a personalized experience based on their unique visual features. Also, they allow an exploration of genetic relationships and data correlation with others to question what the analysis of biometric data means and represents in a digital society.
2. Compared to other biometric data such as irises, DNA fingerprints and teeth, the process of acquiring fingerprints is easier and faster due to an abundance of highly developed hardware and open-source software.
3. Participants can freely and easily provide fingerprint data without any inconvenience or difficulty in art exhibition spaces. In this artwork, I am not acquiring any secondary personal identity data from participants, so

[5] http://www.scientificamerican.com/article/are-ones-fingerprints-sim/

it is impossible to track their identities or illegally store their identity data.

5.2. Fingerprint Analysis

In this section, more detailed fingerprint analysis in genetics, palmistry with behavior analysis and biological characteristics will be discussed.

5.2.1. Genetic Information

Genetic information directs cellular function, serves as a link between generations, and influences an individual's appearance. Some aspects of appearance are similar among all individuals of a species (i.e. those characteristics that define the species). However, for individuals within the species, many genes and external factors determine each aspect of the individual's physical appearance. There is an interaction of the two types of factors – genetic and environmental factors that impact the formations of the fingerprints. When subtle variations in the symmetry of a volar pad are created, any one of the numerous genetic or environmental factors affects the creation of a pattern on the fingerprints during the critical stage; the slight deviation in the normal development symmetry of the volar pad becomes the resulting pattern type eventually. Even though the genetics affect to create similar patterns, many researches and examples show that environmental factors impact the creation of detailed ridge formations. For example, the ultimate example of the role of the environment in friction ridge formation is monozygotic twins, who share identical genetic information and very similar intrauterine environments, but on many occasions have very different patterns. (Holder, Robinson and Laub, 2011)

There have been two interesting familiar studies. According to a research conducted by Jamshed Mavalwalar, the intratribal variations in friction ridge pattern frequencies were greater than intertribal variations. (Holder, Robinson and Laub, 2011) Furthermore, intraspecies variations in primates were greater than interspecies variations. The research suggests that multiple genes affect pattern formation and that those genes interact with respect to final pattern characteristics. (Holder, Robinson and Laub, 2011) Furthermore, the medical communities have researched the impact of abnormal fetal development during the critical stage. Lack of medical treatment has impacted the family members by having congenital ridge aplasia and creating ridge anomalies.

5.2.2. Fingerprints in Hand Analysis

Fingerprints have been analyzed in the hand analysis and palmistry in various countries and cultures for a long time. There is a long history in India and China of the use of fingerprints as indications of attributes or character traits. Friction ridge skin impressions were used as proof of a person's identity in China perhaps as early as 300 B.C., in Japan as early as A.D. 702, and in the

United States since 1902. (Holder, Robinson and Laub, 2011) The hand analysis is a field of study that has been researched by therapists, counselors, neurologists and geneticists. It is a means of getting insight into life purpose, which are through analysis of the prints of the hands. It categorizes the fingerprints in four major types and sub-types and read the life purpose based on its locations. The patterns of the fingerprints are based on *henry classification system* as seen in Figure 5.2.1. Henry classification system is a method to sort main patterns of fingerprints in four major types (whorl, loop, tented arch, and arch) developed by Hem Chandra Bose, Azizul Haque and Sir Edward Henry in the late 19th century. (Holder, Robinson and Laub, 2011)

Figure 5.2.1: Four Major types of Fingerprints by Henry Classification[ix]

There have been many organizations and institutions where conduct the research and practices of the hand analysis.[6] Dermatoglyphics Multiple Intelligences test (DMIT)[7] is a commercial product, which suggests multiple

[6] Three major organizations of the hand analysis: http://lifepurposenow.com/, http://www.handanalysis.net/publications.html, http://handpedia.com/

[7] http://www.handresearch.com/news/dermatoglyphics-multiple-intelligences-test-dmit.htm

intelligences (talents) by assessing dermatoglyphics and fingerprints. (see Figure 5.2.2) In Korea, by using the DMIT product, high school students could learn what types of occupations would fit for their future based on the fingerprint analysis. Most of these researches and products are not based on scientific investigations due to the lack of reasonable proof and fully enough database. Furthermore, it is hard to verify the truth of the results of the test in near future.

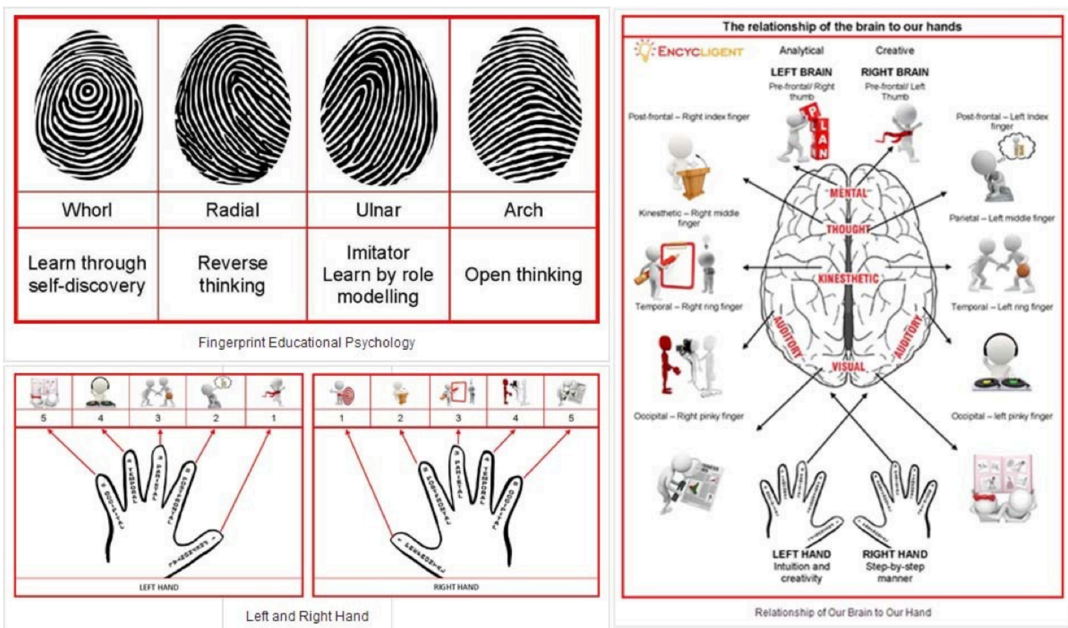


Figure 5.2.2: Dermatoglyphics Multiple Intelligences test (DMIT) based on the Hand Analysis.[x] The illustration is a compilation of illustrations presented by Encycligent.[xi]

5.2.3. Identification/Individualization with Fingerprints in Technology

In the fields of science and technology, there has been a long story of using fingerprints as identification in many ways. Friction ridge skin impressions were used as proof of a person's identity in China and Japan in old days, by printing and carving the patters on papers and stones. Megalithic artworks are examples of ancient artifacts displaying how the identification has been used. However the pattern categorization system was not clear then. Based on many preliminary researches, henry classification system has been defined. The Henry Classification System and the individualization of criminals became standard practice in England and was adopted in most English-speaking countries. (Holder, Robinson and Laub, 2011) The research and practical knowledge accumulated over the course of many centuries support the development of forensic science and technology.

The most challenging part for fingerprint analysis was the fingerprint feature extraction algorithms and how to index fingerprints. First, the binarization algorithm was used to convert fingerprint images to the grey-scale-enhanced fingerprint images, where all black pixels correspond to ridges and all white pixels correspond to valleys. The resulting image from the thinning algorithm is called a thinned image or skeletal image. (more details will be described in next section. A minutiae detection follows after the step, and the post-processing include an examination of the local image quality, neighboring detections, or other indicators of non-fingerprint structure in the area. Fingerprint matching can be defined as the exercise of finding the similarity or dissimilarity in any two given fingerprint images. Regarding the index and retrievals, there are three ways to index the fingerprints like below (Holder, Robinson and Laub, 2011):

- *Hypothesized class only—Only fingerprints belonging to the class to which the input fingerprint has been assigned are retrieved.*
- *Fixed search order—The search continues until a match is found or the whole database has been explored. If a correspondence is not found within the hypothesized class, the search continues in another class, and so on.*
- *Variable search order—The different classes are visited according to the class likelihoods produced by the classifier for the input fingerprint. The search may be stopped as soon as a match is found or when the likelihood ratio between the current class and the next to be visited is less than a fixed threshold.*

5.3. Visual Feature Analysis of Fingerprints

(Portions of this section were previously published as (Han, Han and Wright, 2013), and have been reproduced with permission.)

Fingerprints can be acquired by using all kinds of equipment including image scanners widely used in home and office environments as well as basic fingerprint sensors. However, to achieve high-quality fingerprint images, a professionally developed fingerprint sensor is required. In general, users can provide fingerprints by placing their fingers on the sensor. During this process, the user can express intent by varying the amount of pressure and extent of the contact, e.g. pressing hard and giving contact with a large extent of the fingerprint, or pressing softly to give contact with only a partial area of the fingerprint. In order to obtain a user's intent via fingerprint image acquisition, it is a pressure and extent-variant must be obtained. Furthermore, extracting the user's intent in addition to widely used fingerprint-specific features such as minutiae, additional visual feature extraction based on image processing is required.

(a) (b) (c)

Figure 5.3.1: Visual feature extraction of a fingerprint sample from FVC2004 dataset. Image skeletonization and minutiae analysis are applied to find singular points on the fingerprint.

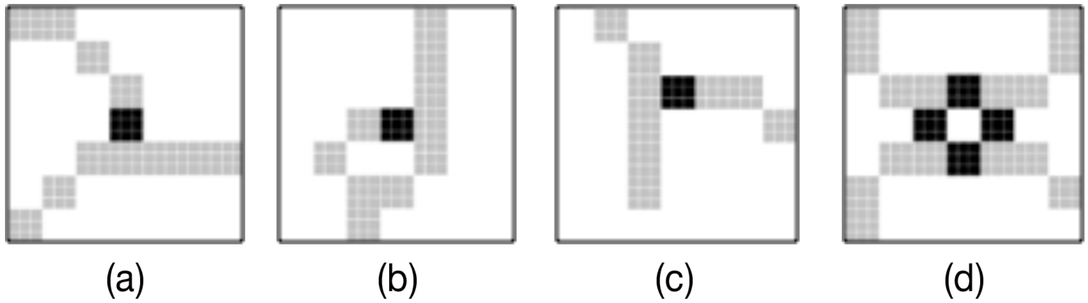


Figure 5.3.2: The examples of four major singular minutiae in our fingerprint image analysis approach: (a) bifurcation, (b) lake, (c) spur, and (d) crossover.

Figure 5.3.1 shows how basic visual features are extracted from a fingerprint image obtained from a user. First, a gray-scaled fingerprint image is processed by thresholding the intensity of the image. This step is required to discriminate the ridges and valleys of the fingerprint. The next step, skeletonization, eliminates pressure-specific information from the fingerprint. For example, if the fingerprint was provided by applying a high degree of pressure, more ridges would appear and the sections of the valleys would decrease. This difference caused by pressure variation can affect the overall task of fingerprint sonification. To this end, image skeletonization is applied on the ridges, the black lines shown in Figure 5.3.1 (a) thresholded image, in order to normalize the portion of the ridges and valleys as shown in Figure 5.3.1 (b). Finally, singular points among the detected ridge skeletons, the minutiae, can be detected by tracing and distinguishing the branches. In this approach, four singular minutiae were detected, which are bifurcation, lake, spur, and crossover as shown in Figure 5.3.2. Due to their uniqueness, the extracted features are specific to individual human identities, so they are widely used in human identification based on fingerprint sensing systems.

In Digiti Sonus – Interactive Fingerprint Sonification – which I introduced at the 2012 ACM Multimedia Conference (Han, 2012), I described sonification based on visual feature extraction from a scanned fingerprint image. In this research, the sound results had a limited range of timbre and frequency, so users had difficulty understanding the uniqueness of each fingerprint. Furthermore, one-directional scanning was too limited and resulted in an overly uniform range of sounds due to the use of only a single animation direction. I decided to explore more dynamic ways of reading through fingerprint patterns. Key insights over the past year have led to improvements in every aspect of the system. The most significant improvement is in the diversity of the output sound using the diverse visual features of the fingerprints, which were presented at the NIME 2013 Conference. (Han, 2013) More details of the visual features of fingerprints are analyzed below.

5.3.1. Position of Minutiae

The *minutiae,* the ridge characteristics of fingerprints, can be extracted through the process of image skeletonization as described above and shown in Figure 5.3.1 and 5.3.2. The two most prominent local ridge characteristics, or *minutiae*, are 1) ridge ending and 2) ridge bifurcation. A ridge ending is defined as the point where a ridge ends abruptly. A ridge bifurcation (Hong, Wan and Jain, 1998) is defined as the point where a ridge forks or diverges into branch ridges. A typical fingerprint contains about 40–100 minutiae. Usually, automatic fingerprint matching depends on the comparison of these minutiae and their relationships to make a personal identification (Lee and Gaensslen, 1991).

Thus, the positions of minutiae are the key information used to recognize the distinctions of fingerprints, so they are widely used for identification purposes. I therefore chose this unique characteristic to be the most significant factor in sonification. For the sake of simplicity, the type of each minutia is ignored.

5.3.2. Area, Pixel Range, and Push Pressure of Fingerprints

Figure 5.3.3 (left) shows several results of placing the fingers on the fingerprint sensor screen with varying positions, orientation, and pressure. Some fingerprints are larger than others and fill the screen completely, while others only cover a small portion of the screen. In addition, some images are brighter whereas are darker. Figure 5.3.3 (right) shows two images made with the same finger, but the image on the left is darker while the image on the right is larger.

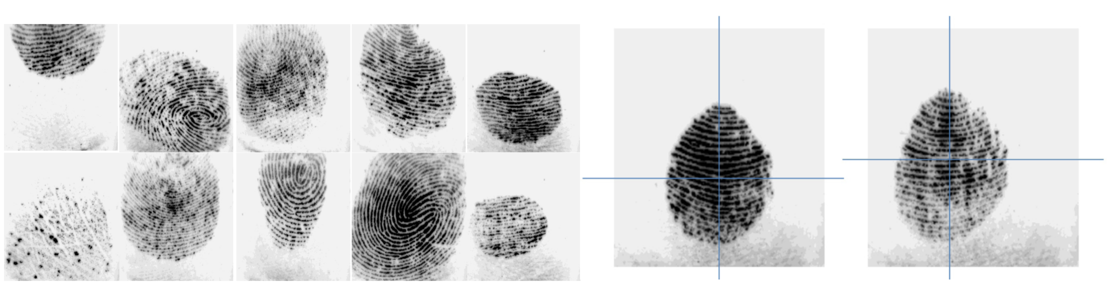


Figure 5.3.3: (Left) Various captured fingerprints (Right) two images captured from a fingerprint with different push pressure.

In the first step of my analysis, only those pixels over a given brightness threshold are selected; for example, the red dots in a fingerprint image indicate the selected (sufficiently bright) pixels. The "position" of the fingerprint as a whole is the 2D centroid of the locations of the pixels over the threshold. The "area" of the fingerprint is simply the number of pixels above the threshold. Finally, the push pressure is the mean brightness of the pixels over the threshold.

5.3.3. Angle of Fingerprint

Users can apply their fingers to the fingerprint sensor at any angle. Users normally touch the sensor at an angle close to 0° (perfectly vertical orientation), but often users may slightly rotate the finger, generally depending on the particular finger (thumb, index, etc.) and hand (left versus right). My analysis of the fingerprint angle is based on PCA (Principal Component Analysis) (Pearson, 1990). Again, the input data are the x and y positions of the pixel above the brightness threshold. These data points are normalized by the mean of each dimension. Next, by computing eigenvalues and eigenvectors, the principal components are acquired. I regard the first eigenvector (principal component) as the direction of the input fingerprint image. Since principal components are always orthogonal and our data is two-dimensional, the second component gives no additional information. Note that for a given physical angle of the user's finger on the sensor, differences in push pressure, calculated by determining which pixels are above the threshold, may also affect the detected angle to some degree.

5.4. Fingerprints as Sonic Identity

Digiti Sonus is an interactive audiovisual art installation based on fingerprint sonification. Transforming the unique patterns of fingerprints into a sonic representation allows the audience to experience the discovery of sensory identities; from an artistic perspective, finding their own sonic identities through the fingerprints gives a unique experience to the audience. I treat the distinct visual features of fingerprints as an open musical score whose performance can be executed in diverse ways. By controlling the starting point of animated visuals, the predetermined musical notes can be reorganized in a different order and duration.

Fingerprints provide rich and detailed input data suitable for expression via musical parameters. I believe that delivering this data in immersive, sensory ways allows for an easier and simpler understanding the complicated patterns of fingerprints. Visitors who experience the installation can “perform” musical sound (albeit in an extremely limited way; see next section) without any difficulty, providing input that results in musical sound.

This artwork is designed as either a gallery installation or a software/application. In a gallery setting, the audience can touch a fingerprint sensor and experience the audiovisual output in real time in the immersive environment. In software or application form, users can input their fingerprints via their own sensor and observe the sonification process, making it accessible to children and students for the purposes of aural attention or educational expression.

5.5. Skin Pattern Analysis and Sonification

In this section, different approaches and technical practices for analyzing skin pattern data are discussed. While working on fingerprint data analysis, the idea of expanding the boundaries of body data was devised. Rather than limiting the data to only certain areas of the body, I and my collaborator, Byeong-Jun Han could open up the possibilities to a larger area encompassing the entire human body. Instead of limiting biometric data to the fingerprints or irises, this partial research expanded the spectrum of data to include the skin over the entire human body. The goal of this partial research is different from the main research, which focuses on using fingerprint data. In this practice, the diversity of skin patterns and textures from each part of the body becomes a resource to prove that it can create subjectivity of sound from one person's body. Therefore, each individual body could become a single and unified instrument creating different sounds by exploring the position and condition of the body. The original idea and problems were addressed by myself and technical implementations were developed by Byeong-Jun Han. The final result was presented at the ICAD 2014 conference. (Han and Han, 2014)

5.5.1. Skin Pattern Analysis and Challenges

Skin patterns are not as clear as other biometric data such as fingerprints, irises, or earlobes. It varies depending on the conditions and locations of the body parts. Therefore, analyzing the subtle differences of skin patterns is particularly challenging because many techniques for image processing must be used concurrently. In order to solve this problem, this research employed non-negative matrix factorization (NMF) (Lee and Seung, 1999) to learn the acquired skin pattern image and discover new image features. NMF[8], known as also non-negative matrix approximation, is commonly used for a variety of fields such as image processing, computer vision and audio signal processing. In addition, parameter sonification mapping (PMSon) allowed us to create a connection between the learned features and the parameters by sound. In order to optimize and discover diverse aspects of representation learning and parameter mapping, experiments were conducted under the acquired skin pattern image dataset using many configurations. The aim of this research includes two main goals: 1) to propose a multimodal interface for users to explore their sonic differences using skin patterns, and create various sound compositions using NMF-based visual feature extraction and learning-based PMSon; 2) to suggest a possible way to allow visually impaired people to be able to explore their bodies through sound.

[8] Non-negative matrix factorization (NMF) is a group of algorithms in multivariate analysis and linear algebra where a matrix V is factorized into (usually) two matrices W and H, with the property that all three matrices have no negative elements. This non-negativity makes the resulting matrices easier to inspect. (Link: https://en.wikipedia.org/wiki/Non-negative_matrix_factorization)

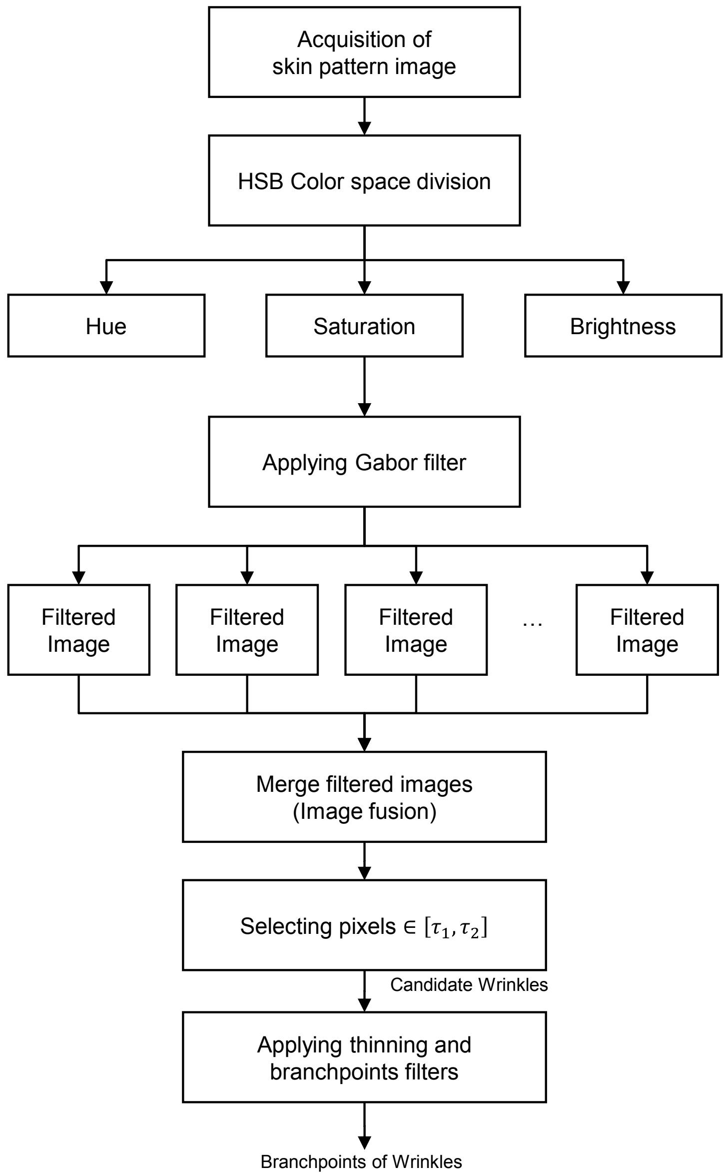


Figure 5.5.1: Overall process for skin pattern analysis

As described above, it is difficult to analyze personalized features from acquired skin pattern images due to their unclear patterns. Instead, each of the skin features can be mapped to parameters as subjective representations of the data input rather than distinct characteristics of each person. One problem in the parameterization of skin features is that the visual features on the skin pattern images are not uniformly shaped. In other words, it is hard to define the global skin features of a skin pattern image. For example, a palm image may contain clear wrinkles and strong palm lines. However, there are also many small wrinkles distributed on the palm along with the clear palm lines, which presents a challenge for in-depth analysis. Also, skin pattern images acquired from different body locations have varying amounts and distributed positions of visual features; for instance, data acquired from an arm can be different from data acquired from the legs due to differences in the distribution of hairs, pores, and wrinkles on the skin. For the above reasons, my method does not consider global skin features but only extracts locally distributed diverse skin features. The most dominant features on the skin patterns are the wrinkles. In order to extract the wrinkles on skin pattern images, the multispectral analysis proposed by Zhang et al. (Zhang 1998) was applied. However, instead of using their original approach, some parts of the processing steps were modified in order to extract not only the major palm lines but also the small wrinkles on various body locations. The main improvements of the technique are as follows: 1) Instead of using the RGB color mixture and NIR band, the saturation band from the in HSV color space was extracted because the saturation information is clear enough to extract the wrinkles, and it is robust even if the angles of the camera or the positions of external lights are changed; 2) the Gabor Filter was used as seen in Figure 5.5.1, which is used commonly in image processing, named after Dennis Gabor. It is a linear filter used for edge detection.

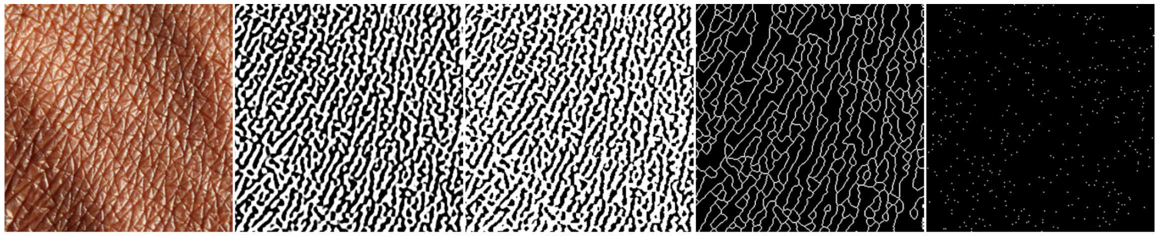
Frequency and orientation representations of Gabor filters are similar to those of the human visual system, and they have been found to be particularly appropriate for texture representation and discrimination. (Feichtinger and Strohmer, 1998) The Gabor filter (Zhang 1998) was considered with six parameters instead of the original Gabor function with four parameters in Zhang et al.'s method; 3) The number of Gabor filters was increased to sixteen for increased accuracy in order to extract candidate wrinkles. Figure 5.5.1 depicts the overall steps of multispectral analysis. In the pre-processing stage, a skin pattern image is divided into multiple color bands. For example, in the RGB color space, the image is divided into red, green, and blue bands. Since the saturation band is able to reveal most of the wrinkles on the skin pattern image, this approach only considered the saturation band in the HSV color space. Next, the Gabor filter was applied to the saturation image in order to discover the directivity of the wrinkles on the image. The Gabor function is defined as the following:

$$\mathrm{g}(x, y, \sigma, \theta, \lambda, \psi, \gamma) = e^{-\frac{x'^{2}+\gamma^{2}y'^{2}}{2\sigma^{2}}} e^{i\left(2\pi\frac{x'}{\lambda}+\psi\right)} \qquad (1)$$

In equation (1), x and y are two-dimensional coordinates specified by x^'=xcosθ+ysinθ and y^'=-xsin θ +ycos θ , σ is a standard deviation for Gaussian function, θ is the Gabor function's angle, λ represents the wavelength of the sinusoidal factor, ψ is the phase offset, and γ is the ellipticity of support of the Gabor function. Among these parameters, fixed values were assigned for σ, λ, ψ, and γ, because only angle θ of the Gabor filter was an important factor for detecting wrinkles on the skin pattern image. With (σ,λ,ψ, γ)=(4,8,0,1), hence, the reduced form of the Gabor function is defined as the following:

$$g(x, y, \theta) = e^{-\frac{x'^2 + y'^2}{32}} e^{i\frac{1}{4}\pi x'} \qquad (2)$$

Angle θ was divided into sixteen steps in (2). In other words, θ in the Gabor function was set to jπ/8, where j=0,1,…,15. Figure 5.5.2(b) and (c) show examples of filtered images created in the steps in equation (2). On the other hand, since each filtered image shows only partial wrinkles, it is impossible to select entire wrinkles without merging all the filtered images. One simple solution to merge the filtered images is to average all the filtered images. This guarantees that all the energy of each pixel in the merged image is within the bounds of the Gabor filter response. After merging those filtered images, the wrinkle candidate pixels are selected within a predefined statistical range. Figure 5.5.2(d) shows an example of the selected wrinkle candidate pixels.



(a) (b) (c) (d) (e)

Figure 5.5.2: An example of skin pattern analysis: (a) original image, (b, c) filtered images, (d) selected wrinkle candidates (e) selected branch points

A standard deviation of each pixel was grouped within the range of $[0,\infty)$, because the statistical distribution of the saturation values of pixels in the original image cannot be predicted. In this approach, it was assumed that the saturation values follow Gaussian distribution and the bounding parameter was selected as the standard deviation. After selecting the candidate pixels, this method applied thinning filters to the extracted skeleton structures of the candidate pixels only, and selected the ridges and valleys of the extracted skeletonized structure. Figure 5.5.2(e) depicts an example of skeletonization and selected branch points.

The skin pattern pixels acquired from the branch points of the local skin patterns need to be represented by limited numbers of parameters. However, in general, it is difficult for sonification designers to parameterize such local skin patterns due to a lack of knowledge about dermatology. Instead of using such preliminary knowledge (dermatological information or related experience), non-negative matrix factorization (NMF) (Lee and Seung, 1999) was applied to a group of local skin patterns and used to extract common patterns from them.

NMF was adopted rather than other well-known factorization methods, such as principal component analysis (PCA), because it does not require learning statistical distribution of such local skin patterns.

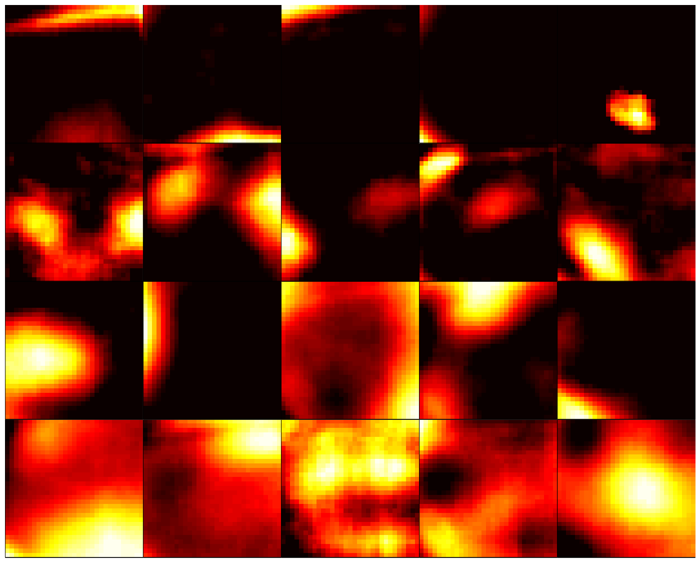


Figure 5.5.3: Basis images from local skin pattern images selected by NMF.

Local skin pattern images should be extracted before applying NMF in order to acquire basis patterns from a group of local skin pattern images. For a skin pattern image, $I(x,y) \in R^{(N_x \times N_y)}$, and branch point $P_k=(x_k,y_k)$, where $k=1,2,\cdots,N$, is extracted using the visual feature extraction approach described in Section 3.2. In our next step, local skin pattern $I_k(x,y)$, where $x \in [x_k-N, x_k+N]$ and $y \in [y_k-N, y_k+N]$, is selected. In this approach, N is set as 5, and therefore the size of each local skin pattern image has the dimensions of 31×31=961. Also, I set a number of latent variables in NMF to 100. Figure 5.5.3 shows examples of selected local skin pattern images and basis vectors trained by NMF.

5.5.2. Skin Pattern Sonification

The visual features of skin patterns extracted from the process described above contain the dataset that can be mapped to parameters in data sonification. In order to sonify our data, we used Parameter Mapping Sonification (PMSon), which is the most common and easiest way to sonify data using and controlling multiple parameters. PMSon involves the association of information with auditory parameters for the purpose of data display. (Chowning, 1973) Multivariate data is suitable for display in PMSon because sound is inherently multidimensional. PMSon has recently been used in a wide range of applications, products and fields. In order to select the methods of mapping the data, sonification designers should examine possible mapping strategies to scale the data to the parameters. The mapping strategies should consider how the data is fitted for auditory display, which sound parameters should be used, and how to scale the data to the chosen parameters. It is also based on cognitive science due to the auditory stimuli of the human body. In order to find the best PMSon method, F. Grond and J. Berger suggest a general design process of effective PMSon (Chowning, 1973); data is selected and prepared from the data domain and, through the mapping function, it is tuned to the parameters of sound synthesis. Data processing moves towards the sections of the parameter domain, signal domain and human perception, which move backwards to the previous steps to tune the process for achieving the best results. As the process suggests, the design of PMSon has an interplay of connection between the data and the signal domains. Iterating the process in both realms is the key point in creating effective sonification.

In this research, I mapped the visual features of skin pattern data into sound parameters by using machine learning techniques. As described above, NMF was used to parameterize skin pattern images, and the represented visual parameters are connected to sound parameters through support vector regression (SVR). In order to automatically map the visual features to sonification parameters, support vector regression (SVR) (Druker, 1996) was employed as a mapping method. For representing multidimensional sonification parameters in FM synthesis, it is essential to generate multiple regression models to be mapped in the parameters. In the training phase, I assumed that pairs (I_k,S_k) of training data are provided, where I_k is an extracted visual feature, S_k is a sound parameter, and k=1,2,…,K is an index of the pairs of training data. If those two values (I_k,S_k) are acquired, users can simply enter them in the SVR method. In other words, sonification designers can create their own skin pattern image-to-sonification training and generate skin pattern sonification models using this methodology in a simple and easy way. A detailed explanation of the parameters and configurations for the training method will be provided in the next section.

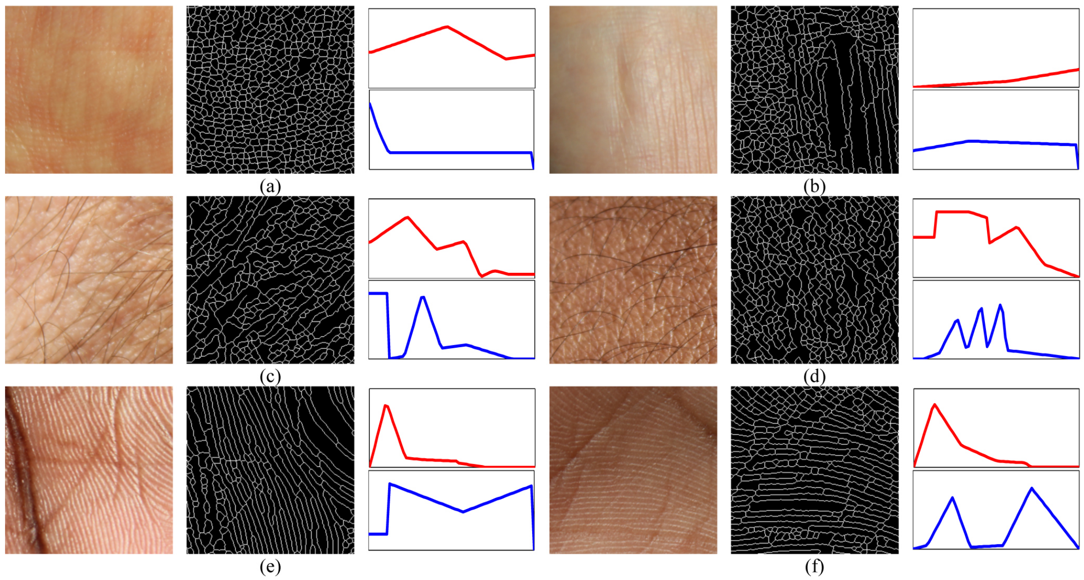


Figure 5.5.4: Each skin pattern image group consists of (left) a raw image, (center) a skeletonized image to find branch points, modulation envelope (top-right, red line), and, amplitude envelope (bottom-right, blue line). (a) and (b) are comparably plain images and generated simple envelops of both modulation and amplitude. (c) and (d) are the most complex images with some noise (due to hairs) and formed envelopes with dramatic changes. Finally, (e) and (f) are not simple images; however, they show constant patterns in their raw images.

5.5.3. Examples and Results

Figure 5.5.4 shows a selected result of skin pattern sonification, in which original images were acquired from diverse body parts such as palms, arms, and legs. Mostly, the body parts that consist of a spread distribution of wrinkles showed a lower number of branch points, and therefore, such skin textures were sonified in a much simpler way. On the other hand, skin pattern images from body parts that consist of complex skin patterns such as having many wrinkles, pores, hairs, etc., generated very unusual sounds using our approach. This implies that the number of branch points from visual feature extraction in

Section 5.5.1 is directly related to the complexity of sonification and timbre of sound.

In the case of local skin pattern images, used as the visual features in regression models, which predict sonification parameters, it seems that the complexity of local images was related to the shapes of the modulation index and amplitude envelopes. If the local skin pattern images themselves are very complex and are represented with a complicated combination of learned basis vectors, the envelopes are also formulated into very complex shapes. Consequently, modulations and amplitude were changed dramatically in FM synthesis steps. In contrast, it was hard to recognize major changes from the sound results created by simple local images in modulations and amplitudes.

However, the small amount of skin pattern data gave insufficient results to show sufficient mapping ranges for learning-based sonification. The examples and demonstrations provided here briefly showed how the learning-based PMSon could be created using the skin pattern data; however, the amount of input data should be increased for greater accuracy and diversity of results. Obtaining a larger quantity of the data will allow us to increase the accuracy and performance of parameter mapping based on the learning process. By acquiring more data from a greater number of participants, we can receive more varied results of sonification. Thus, it is the most crucial part of this kind of learning-based analysis and implementation.

Skin patterns contain very subtle, irregular, and complex data, and it is challenging to examine and understand the data with their unique visual features. For ordinary people who want to create their own sonic signature or explore new musical experiments, skin patterns are promising resources because of their unique personal information and the distinct characteristics of the patterns. However, it is hard to examine the multivariate and complex data with the eyes only. Sonification offers a promising approach for reading and analyzing data since it can support the visuals with a multisensory experience. Thus, the development of data sonification for analyzing skin pattern data is important for the advancement of auditory display, multimodal interfaces, and even medical applications.

The most challenging part of data sonification is to design appropriate strategies to create the connection between the dataset and parameters of sound in order to effectively deliver the data by sound. Multidimensional and complex data acquired from complicated images requires better ways to read the data. As in the experiments mentioned above, machine learning is able to enhance the ways of understanding how to retrieve the right formats of the data, and to find appropriate connections between sorted data and audio parameters.

The framework described here presents research exploring a better way of sonifying the body data images by using learning-based techniques. It is not only beneficial for easy retrieval of the data but also suggest a new method of using sound as an interesting medium to explore the human body in an experimental way. Thus, this framework suggests a new way of creating sound using the body as both a scientific method and an experimental artistic application.

This research is still in the early stages. The other visual features of skin patterns should be investigated, including not only wrinkles and pores but also more dynamic and deeper levels of the skin pattern data. More advanced image processing techniques might be required to retrieve more visual features of the skin patterns. Also, different machine learning techniques can be applied to sort more accurate results. Obviously, more diverse sound synthesis such as additive, granular or wave terrain syntheses could be applied to create diverse timbre and combinations of sounds. The next step of this project is to conduct a user study with various ranges of people to generalize and stabilize the range of the parameters and to enhance the quality of this framework. The comparison between image and sound is a key point, and the results from the study may improve the existing analysis methods.

5.6. Design of Digiti Sonus – Interactive Fingerprint Sonification

This section describes how I sonified and re-formed the 2D fingerprint image into a 3D animated visualization based on the five distinct features described in the Chapter 5.3. Also, the mapping methods used to sonify the fingerprint dataset are described. Figure 5.6.1 depicts the overall fingerprint sonification process including fingerprint acquisition and preprocessing. After fingerprint acquisition is completed and minutiae are extracted, sound filters generated by extracted minutiae are applied to the transformed fingerprint image in the time-magnitude axes.

In addition to the obvious form of interaction of having participants scan their fingerprints, Digiti Sonus also uses the metaphor of expanding circular ripples like those that would arise from dropping a stone into a pond. Alongside the fingerprint scanner is a visually inviting touch screen; when the user touches the screen, it interactively generates an outward-expanding ripple in the fingerprint image, centered on the touch point. I support only one ripple at a time; if a user touches the screen again before the previous ripple ends then the old ripple disappears and a new one starts to expand from the new touch position. This ripple affects both the visualization (as shown in Figure 5.6.2 below) and the sonification (as described in Section 5.6.1. below).

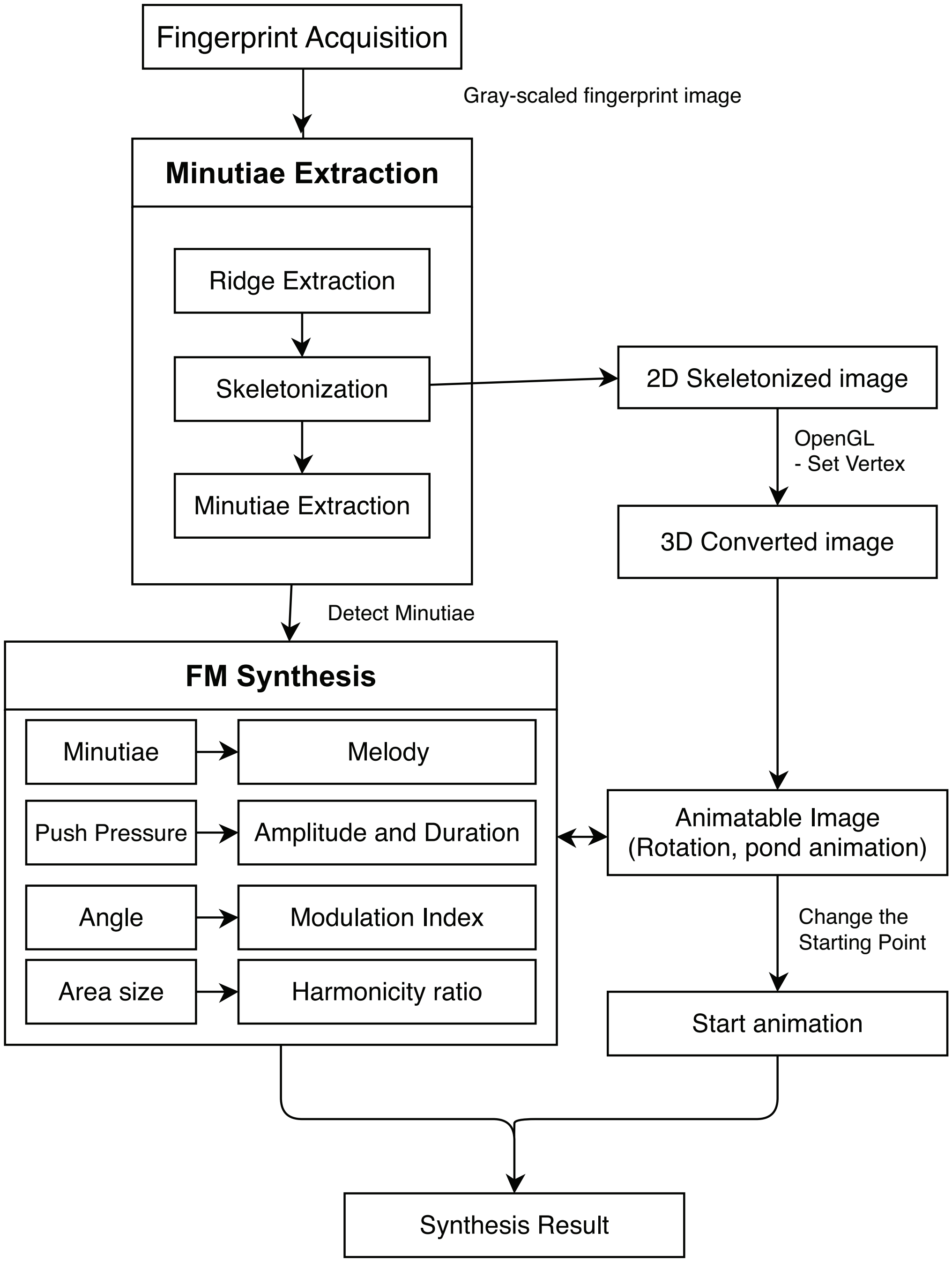


Figure 5.6.1: Overall fingerprint sonification and visualization process

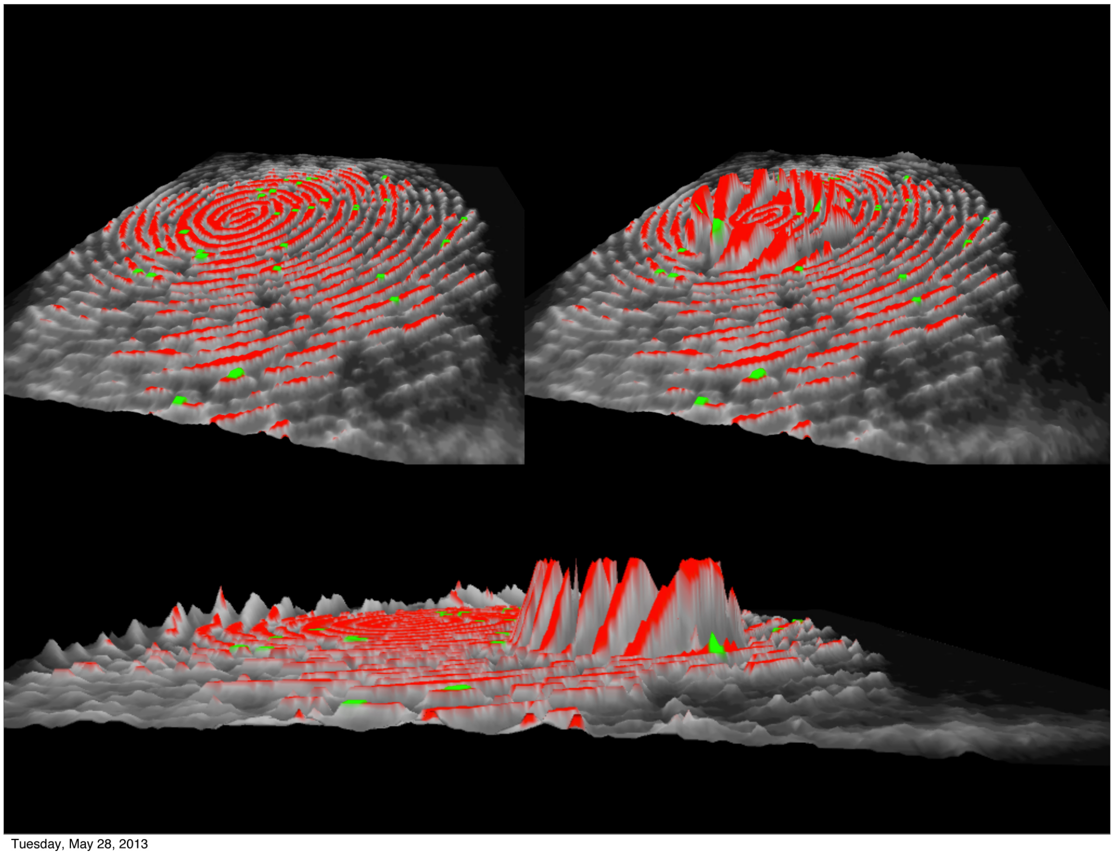


Figure 5.6.2: 3D Visualization and Riffle Effects in Digiti Sonus

5.6.1. Musical Expressions in Digiti Sonus

In early prototypes (Han, 2014), I mapped the positions and number of minutiae into the frequency range of sound by regarding the whole fingerprint image as a magnitude spectrogram, with the x and y axes of the fingerprint image interpreted as the frequency and time axes. In practice, this tended to create a very limited range of output timbres even though the minutiae of all fingerprints are distinctive. In order to broaden the diversity of timbre, I first employed FM synthesis, with the five distinct fingerprint features mapped to synthesis control parameters.

Table 5.6.1: Transforming raw data and perceptual feature into FM Synthesis

Raw Data	Perceptual Feature	Variables of FM Synthesis
Position of minutiae pixel	Position of minutiae	Pitch
Average brightness of ROI pixels	Push pressure of finger	Overall amplitude and duration
Angle of pixels above threshold for selected pixels	Angle of fingerprint	Modulation index
Number of selected pixels above threshold	Area of fingerprint	Harmonicity ratio

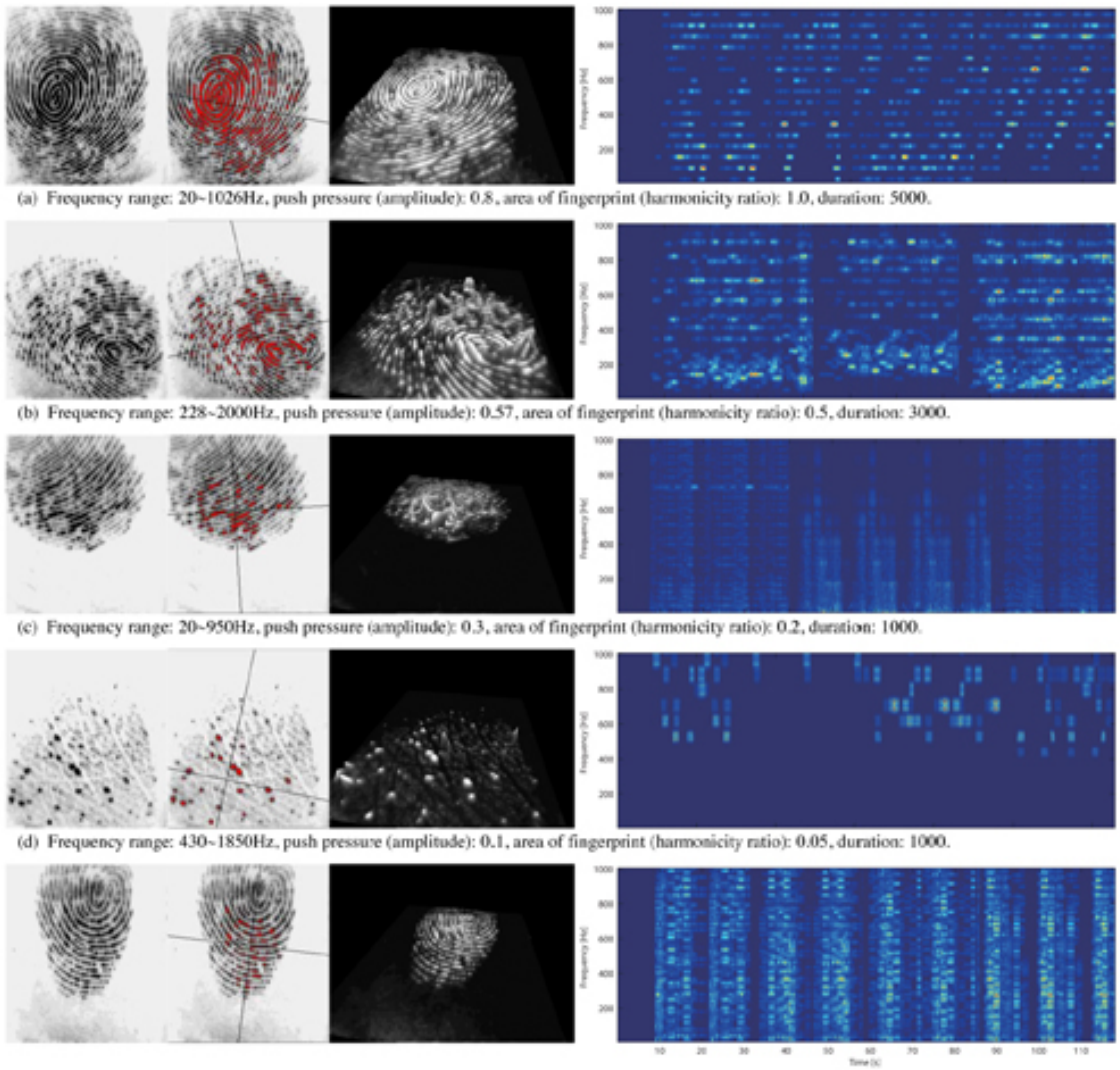
FM (Frequency Modulation) synthesis, discovered by Chowning in 1973 (Chowning, 1973), is a way to alter the timbre of a simple waveform by modulating its frequency with another waveform. In the basic FM technique, a modulator oscillator modulates the frequency of a carrier oscillator (Roads, 1995). One of the most significant benefits of FM synthesis is that a small number of input parameters can easily control a large range of output sounds. This was a main reason we adopted FM, along with the simplicity of implementation. My Max/MSP implementation has four input parameters: fundamental/carrier frequency, amplitude, modulation index (modulator amplitude over modulator frequency), and harmonicity ratio (modulator frequency over carrier frequency). An envelope controls the modulation index over the time of each note. The two floating points of principle components, which I calculated for the angle of fingerprints, change the starting and ending points of the envelope that controls the modulation index. Thus, if the angle of the fingerprint is higher, the angle of the envelope is also higher, which changes the modulator amplitude dramatically. The dramatic changes can be checked on the Figure 5.6.3.

5.6.2. Mapping

The five visual features extracted from each fingerprint are mapped into the control of FM synthesis as shown in Table 5.6.1.

Each minutia corresponds to a note of FM synthesis. The interactive metaphorical stone-in-the-pond ripple triggers that note when the expanding circle reaches the minutia's 2D position. The note's frequency is determined by converting the minutia's 2D position into a single value using the technique of flattening the array of pixel positions: given a 2D (x, y) position where x has a range of 0 to 255 (because of the fingerprint sensor's resolution), the corresponding 1D position is 256y+x.

The fingerprint area is mapped to the harmonicity ratio and the angle is mapped to the starting and ending points of a single envelope that controls the modulation index. The push pressure is mapped intuitively to overall amplitude and duration, so that stronger imprints onto the fingerprint scanner result in stronger sounds.



(a) Frequency range: 20~1026Hz, push pressure (amplitude): 0.8, area of fingerprint (harmonicity ratio): 1.0, duration: 5000.

(b) Frequency range: 228~2000Hz, push pressure (amplitude): 0.57, area of fingerprint (harmonicity ratio): 0.5, duration: 3000.

(c) Frequency range: 20~950Hz, push pressure (amplitude): 0.3, area of fingerprint (harmonicity ratio): 0.2, duration: 1000.

(d) Frequency range: 430~1850Hz, push pressure (amplitude): 0.1, area of fingerprint (harmonicity ratio): 0.05, duration: 1000.

(e) Frequency range: 130~750Hz, push pressure (amplitude): 0.3, area of fingerprint (harmonicity ratio): 0.25, duration: 500.

Figure 5.6.3: Five input fingerprint images, analysis, 3D displays, magnitude spectrograms generated from the input fingerprint images, and ranges for each of the parameters.

The mapping to FM synthesis is intuitive, and obvious changes in the fingerprint are reflected by equally obvious changes to the sound. A larger and brighter fingerprint has a higher magnitude and longer duration of sound. A higher number of minutiae results in a more diverse pitch range and more total notes, often giving the perception of having varying melodic lines. Users become clearly aware of the relationship between the area and brightness of their fingerprints and the harmonicity, magnitude, and melody range of the sound.

5.6.3. Aesthetic Property of the Fingerprints

When magnified, the complex patterns of fingerprints reveal aesthetically engaging dimensional structures, their transformation in scale suggestive of land art such as that created by artists Robert Smithson, Richard Long and others. Yves Michaud mentions that biotechnological art with new media and materials is not for the production of things but for the creation of experiences (Kac, 2007). The ultimate purpose of the aesthetic appeal of beauty can be a creative art that can open up the gates for new possibilities in investigating developments beyond any of our present concepts or imagining.

The installation Digiti Sonus creates a unique, animated three-dimensional, grayscale images that are very minimal, but with a strong contrast that focuses solely on the *materiality* using formation of lines on the fingerprints. Turning the two-dimensional lines of the fingerprints into the three-dimensional dynamic images creates an interesting result on the screen (Figure 5.6.4) The final images look like moving mountains or valleys, as our fingers picture a small world of nature. The three-dimensional images are projected at the screen's center in the oval shape of the projection walls, which mimic the shapes of our fingertips. Thus, the original data still remains the same, but the audience can manipulate the details and have different sensory experiences. In addition, these scanned fingerprint images are transformed into a musical score, thus animating a three-dimensional visualization in which the fingerprints take the shape of a vibrant sonification. The sonic signature of the fingerprints delivers the sonic identity with the simple, electronically generated sound that harmonizes with the simple but strong grayscale images. The resulting projected image and sound vibrations can be considered the artistic representation of an ephemeral shape, a sort of hidden otherness that becomes apparent, giving a sonic quality to something that cannot be seen.

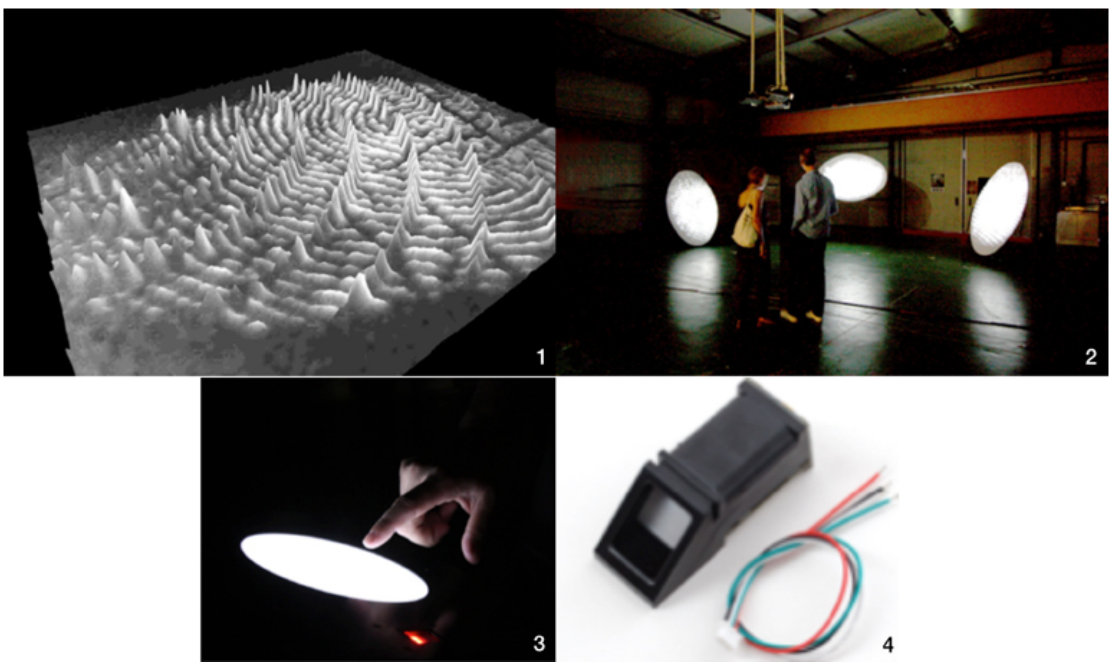


Figure 5.6.4: 3D Fingerprint Image (1), Installation Setup (2), and circular touch screen panel (3), User input devices: fingerprint sensor ZFM-20 (4)

5.7. Technical Implementation

The current version of Digiti Sonus uses mostly the same hardware as the prototype (Han, 2014), including a fingerprint sensor, PC system, and displays. The major differences between the current and prototype versions are as follows: 1) For the fingerprint sensor, I employed ZFM-20 (ZKM-20, Retrieved from adafruit.com) (see Figure 5.6.4 (4)) instead of Nitgen RS232 because of the ease of protocol implementation and circuit configuration as well as the increased scanning speed in particular; 2) I installed multiple displays in order to show 3D fingerprint images in diverse perspectives, and; 3) A touch screen panel interface (see Figure 5.6.4 (3)) allows the user to determine the starting point of sound playback, as described above. The touch screen, which is 10.4 inches wide and has a USB controller, is a type typically found in touch monitors or touch-based interfaces. Users can only touch a certain point on the screen, instead of swiping or dragging their fingers.

Considering the use of multiple displays and running multiple 3D fingerprint image displays in multi displays, we installed high performance VGA, with multiple output connectors, in the PC system. For example, in case of our exhibitions in Media City Seoul, as described above, the PC system with the following specifications was employed: i7-2600 @ 3.40GHz CPU, 16GB RAM, 4TB HDD and 128GB SSD, and AMD Radeon HD 7950 3GB GDDR5 VGA (5 video output).

For image processing and 3D visualization, I used Processing[9], a Java based programming tool. Max/MSP receives the fingerprint data from Processing applets via Open Sound Control (Wright and Freed, 1997) over UDP. Software performance is critical because Digiti Sonus must simultaneously conduct many tasks such as fingerprint sensor control, fingerprint sonification, and real-time 3D rendering. Processing has a severe limitation of being able to use only one CPU core, which I worked around by dividing our implementation into several independent applications communicating over OSC: fingerprint sensor control application, fingerprint sonification application, display application, and broadcasting application. This allows the operating system to dynamically allocate CPU core resources. An additional benefit of this architecture is the scalability of the number of simultaneous displays, which can change frequently depending on the circumstances and conditions of the exhibition space.

[9] Processing: http://processing.org/

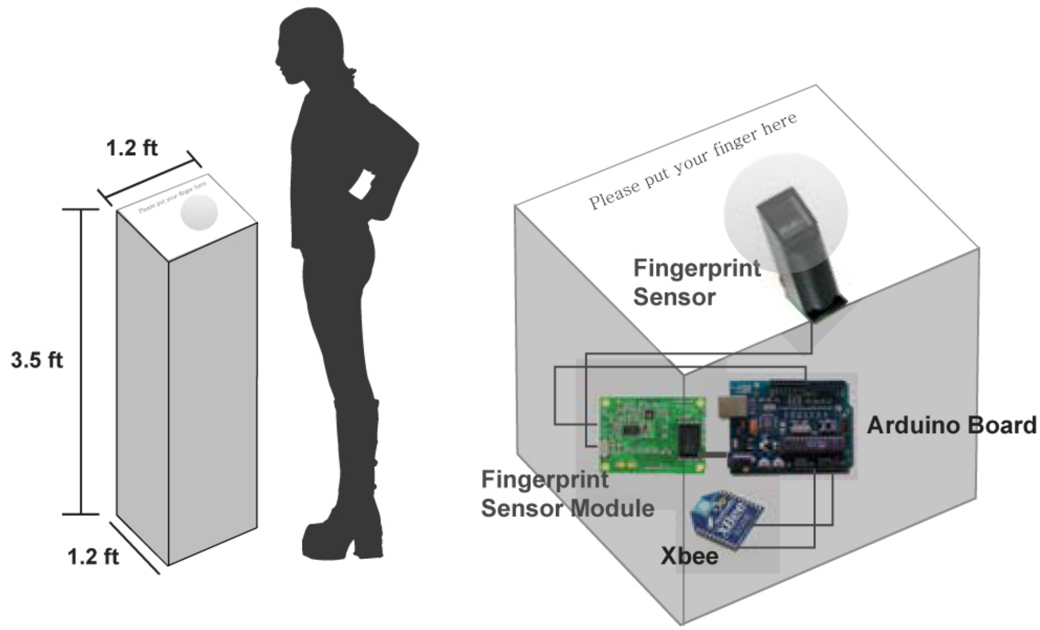


Figure 5.7.1: Fingerprint scanner structure and interface design

Collaboration

Digiti Sonus presents highly interdisciplinary research that integrates artistic expression and practices with technical embodiments. It required many iterative processes and the convergence of different disciplines and specialized fields. In order to conduct successful research, collaboration with creators of different backgrounds and expertise can be a great strategy. Digiti Sonus is a collaborative project between Yoon Chung Han and Byeong-Jun Han. As a principle investigator of the series of the art projects, I developed the main idea on artistic approaches, fingerprint analysis, fundamental studies on visual features of the fingerprint data. My role as an artist was also to develop the key idea on visualization and sonification and installation design. My collaborator Byeong-jun Han, as a technical director and engineer, implemented the 3D visualization, parsing and retrieving of the visual features of the fingerprint data realized in the Processing software environment. More details on the specific roles and contributions on all the publications I and Byeong-jun han presented are described in acknowledgement, Chapter four and Appendix B. In this research on creating personalized biometric data sonification, interdisciplinary collaboration has enhanced the development of various frameworks and practices. Most of the research and practices of Digiti Sonus, the central project of this research, are collaborative in nature.

5.8. Design of Digiti Sonus v2 – Browsing Large Numbers of Fingerprints

The previous interface in Digiti Sonus v1 had two major issues: only one fingerprint could be used at a time, and it had a limited browsing interface. In v1, only a single fingerprint could be captured and analyzed. Thus, it was hard to compare the outcomes generated by the fingerprints of different individuals and recognize how unique they were. This version also used a circular touch screen, which was limited in its scope of user interaction due to having limited functions and features; users could only select or drag the starting point. A more diverse array of functions for user interaction, the potential to create diverse audiovisual effects, and a more intuitive and direct means of interaction through hand motions were necessary. Thus, the new version of Digiti Sonus proposed to implement the ability to browse large numbers of fingerprints and utilize simple and intuitive hand motions with a short-range depth sensor, offering a suitable and advanced approach for improving the original system. Considering the various formats of this project, this most recent version could be exhibited at various locations (e.g., art galleries, public spaces or indoor environments with a desktop application). Based on accurate sensing technology and an easier learning ability in the camera, this advanced version includes several new features for user interaction, which allow observing, panning, zooming in/out, modifying and rearranging fingerprint pieces using various hand motions.

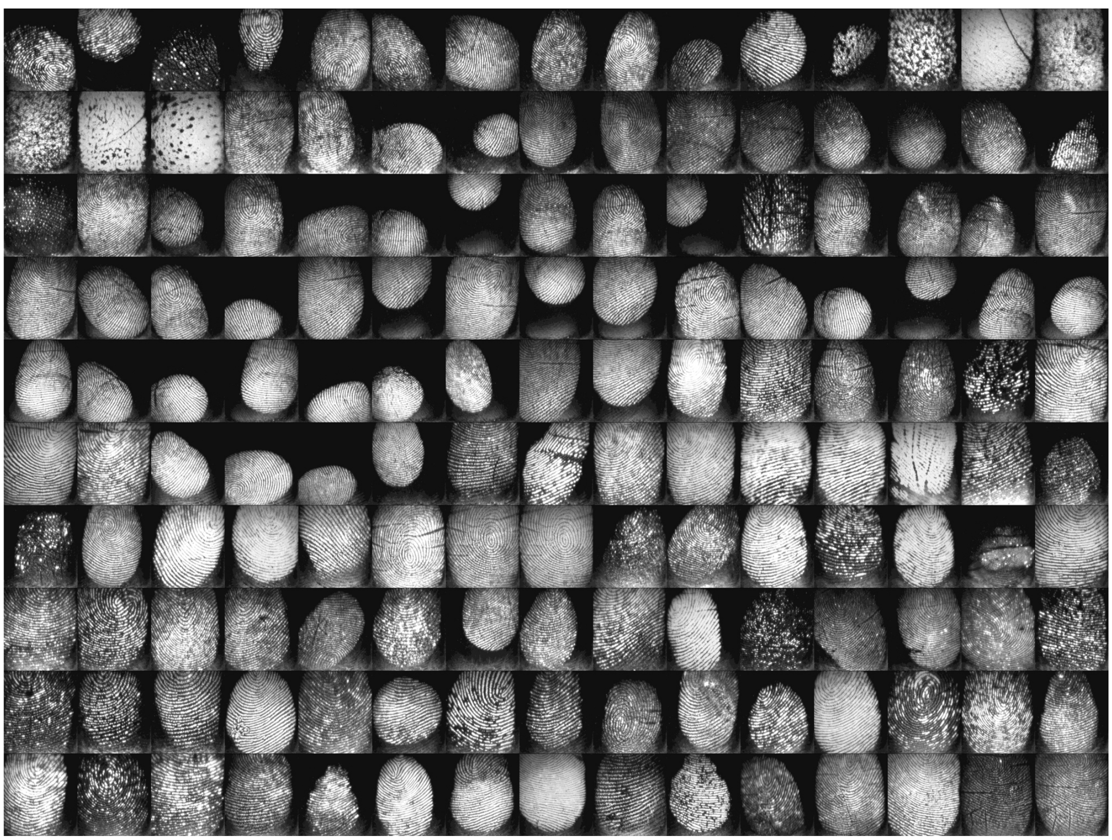


Figure 5.8.1: Browse larger number of fingerprints in Digiti Sonus v2

The concept behind Digiti Sonus v2 is to allow users to explore their own fingerprint patterns via sound and to compare their fingerprints with those of other users by using hand motions. Through this approach, each user's fingerprint can be considered a unique piece of a larger sound puzzle, consisting of a series of collected fingerprint pieces that can be played over time. This unique design interface is formed within a 3D interactive environment controlled by users' hand motions with the use of a Leap motion camera (Retrieved from Leapmotion.com), which is an intuitive and useful camera device capable of tracking the movements of all of a user's fingers with a high level of sensitivity. The detailed process of user interaction in Digiti Sonus v2 is described below. First, a user enters his or her fingerprint through a fingerprint sensor built into a custom-made interface. The scanned image of the fingerprint is then loaded and displayed on the screen, and becomes a part of a group of fingerprint images. Due to privacy issues, the scanned fingerprint image is not saved in our software/database or distributed for any other purpose in the future. A certain number of scanned images are immediately used as short-term data and erased when new fingerprints write over the old ones. The 2D fingerprint images are transformed into 3D images; the height of the 3D vertex on the fingerprint image is determined by the brightness of each pixel in the original 2D fingerprint image. Once the 3D image has been generated, the user can "play" the fingerprint sound by selecting one of the fingerprint images, and determine where to start playing. The selected fingerprint is enlarged and played with sound and a ripple-like animation based on the users' starting point. The user can switch to other fingerprint images to explore the differences in their sounds and visuals. Finally, the user can explore the whole grouped fingerprint sound composition by rotating, zooming, selecting or changing the layout of the images. Over time, all fingerprint images are played as sound, allowing the user to intuitively notice how those fingerprints create different sound compositions.

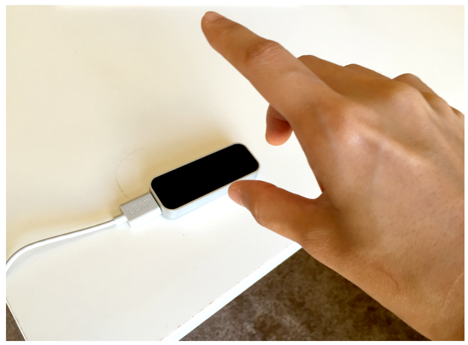


Figure 5.8.2: Leap motion for hand motion

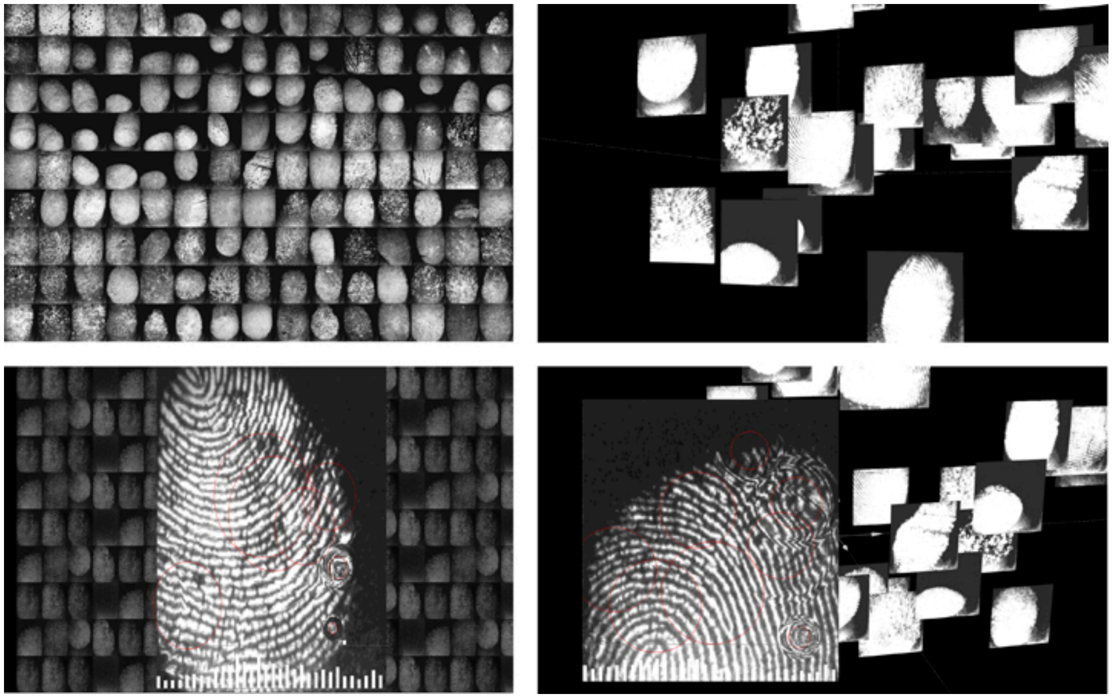


Figure 5.8.3: Test images of Digiti Sonus v2. (Top-Left) Array layout, (Top-Right) a zoomed fingerprint image from array layout, (Top-Right) Random layout, and (Bottom-Right) a zoomed fingerprint image from random layout

Properties of Digiti Sonus v2

Digiti Sonus v2 includes a number of additional features as part of the image manipulation process. These features are controlled by various hand motions, which are mostly dependent on the position, the direction of movement, and the number of fingers that move toward the Leap motion camera. The image manipulation process is divided into two parts: 1) an individual fingerprint piece; and 2) a group of fingerprints. Detailed hand motions for the first process (controlling a single fingerprint image) are as follows:

- Select a fingerprint image: A single finger is placed on one of the fingerprint images and held for a few seconds.
- Play sound and animation for the fingerprint image: The user moves one finger around the inside of the selected fingerprint area.
- Zoom in/out on the fingerprint image: The user moves all five fingers back and forth to zoom in and out of each fingerprint image.
- Change to another fingerprint image: The user moves a single finger outside of the enlarged fingerprint image, and holds it to the other fingerprint image to be selected using the same selection process.

The second part of the process (creating a group of fingerprints) can be described as follows:

- Change the formation of fingerprint images: The default layout is a 2D grid of fingerprint images. However, the user can swipe all five fingers in a fast motion to change the preset layout–(one line, 3D cube, circle or randomly generated layout) that can be selected.
- Scroll through fingerprint images: Using all five fingers, the user can horizontally scroll through the layout of the fingerprint images to discover and navigate between hidden fingerprint images. This applies to all of the layouts described above.

Digiti Sonus v2 focuses on exploring new ways of reading and manipulating fingerprint image data using simple and intuitive hand motions, thus creating personalized artistic experiences for users based upon their own creativity and unique fingerprint data. Compared to the original version of Digiti Sonus, the array of interactions available to the user in Digiti Sonus v2 is much more diverse. This creates the opportunity for a broader range of options for controlling the images, providing greater freedom than other physical interfaces (e.g. mouse, keyboard, or joystick). Using this new approach, I have observed that users are enthusiastic when they participate with our installation. I believe that this approach presents a novel and suitable method for the artistic manipulation of fingerprint data, especially for transforming fingerprint data into sound using hand motions, which has to the knowledge not been previously attempted in the fields of interactive design and art. Digiti Sonus v2 therefore has the potential to become a leading approach for creating novel personalized art while providing an interesting multimodal interaction experience for the user.

5.9. Results and Evaluation

5.9.1. Results

Based on visual feature extraction and sound synthesis, I experimented with the sonification of fingerprints by looking at hundreds of saved fingerprint images acquired from a previous exhibition. From those fingerprints, I selected five distinct fingerprints, which showed each of the unique characteristics of the visual features of fingerprints. Each fingerprint has different ranges and numbers of parameters, and I was able to examine the diversity of sound in each different fingerprint. The detailed parameter numbers and 3D image results are shown in Figure 5.6.3, which also shows the spectrograms of the sounds resulting from this same set of fingerprints.

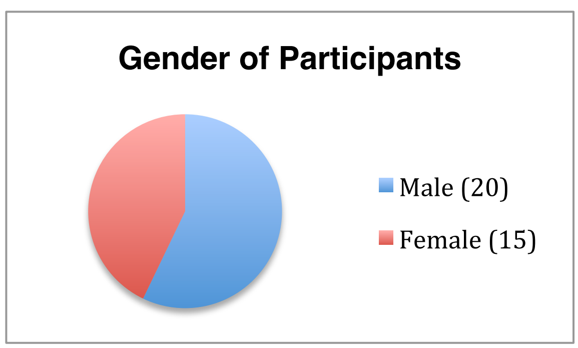
For example, the first fingerprint resulted in a carrier frequency in a low frequency range, creating a harmonic set of partials due to a harmonicity ratio of 1.0. Overall, the long amplitude decay made a metallic bell-like tone. The second fingerprint was similar to the first but had a higher frequency range. The third fingerprint exported the most surreal timbre of sound with a very low carrier frequency range and low amplitude. The fluctuating modulation index of this fingerprint resulted in a vibrating sound. The fourth fingerprint was similar to the third one due to the angle of the fingerprint, but the push pressure was too weak and the overall amplitude was low. As a result of the fifth fingerprint, a low modulation index, a short duration, and a characteristic envelope, spooky fluctuating sounds were created. Hence, the timbres of the sound were all different and had their own signatures, which accomplished our goal of allowing users to experience the distinct sonification of their fingerprints.

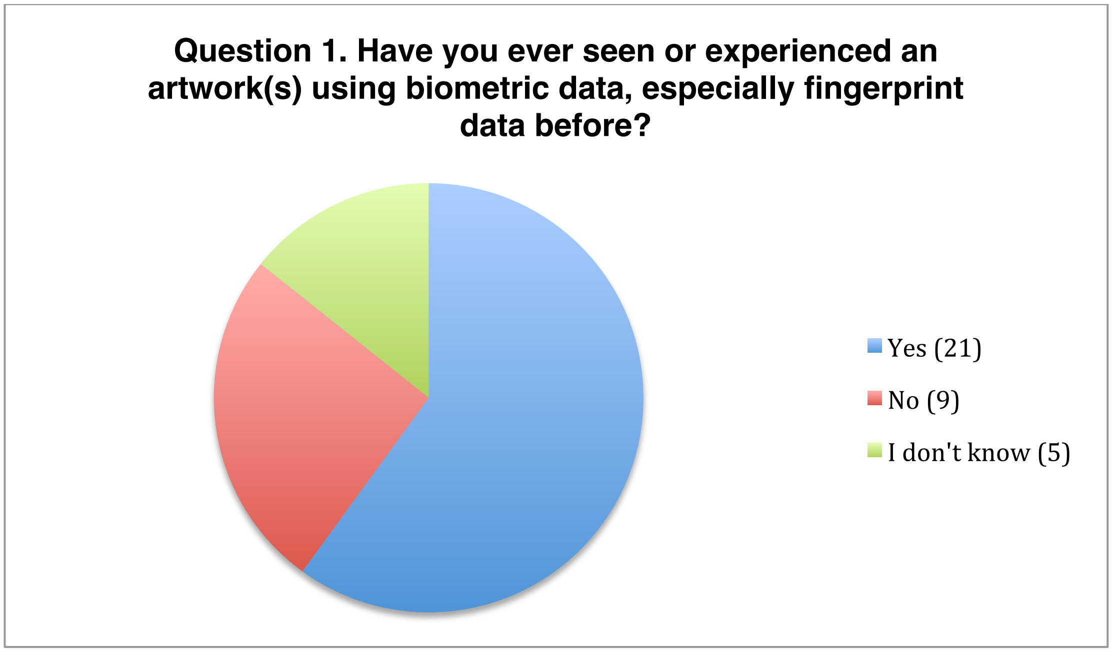
Furthermore, based on the visual features of fingerprint images, I created a web-based data visualization that shows a correlation between the visual features of the fingerprint and their answers from the user evaluations. The purpose of the data visualization is to observe and analyze the hierarchy of the fingerprints based on the visual features, and enhance the understanding of the audience on which groups his or her own fingerprint is categorized. The details of the visualization will be described with screenshot images in next section.

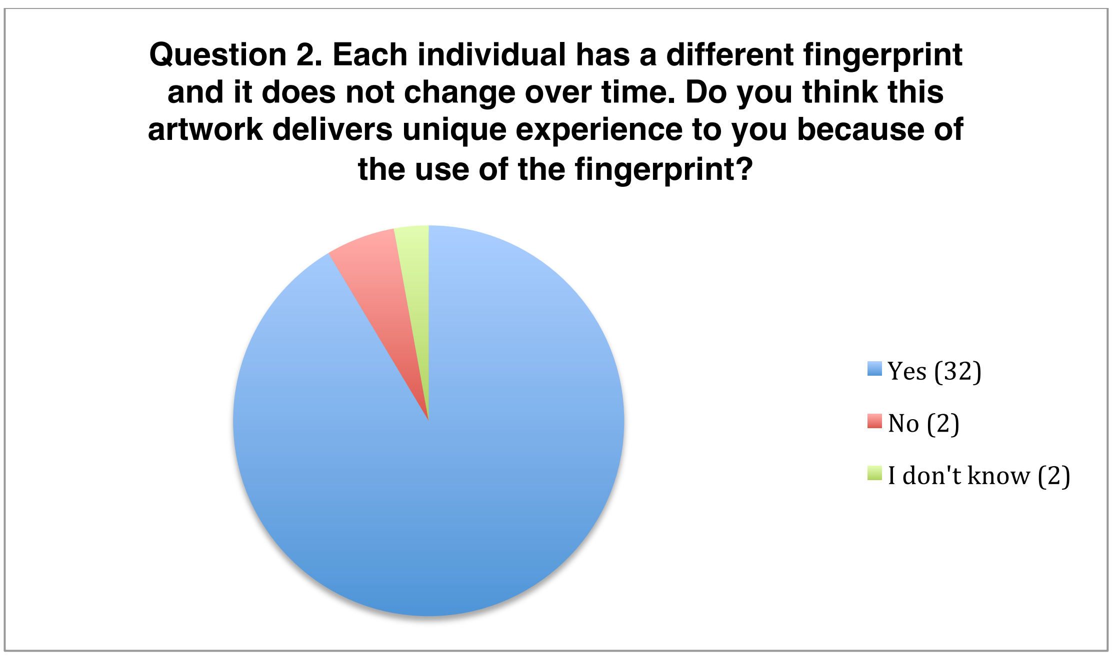
Even though each audience member has unique audiovisual results from the artwork, more observations and analysis on their artistic experience are necessary. In order to understand the personalized and unique artistic experience, user evaluations with relevant questionnaires are necessary. In the next section, the details of the user evaluations and its results will be described.

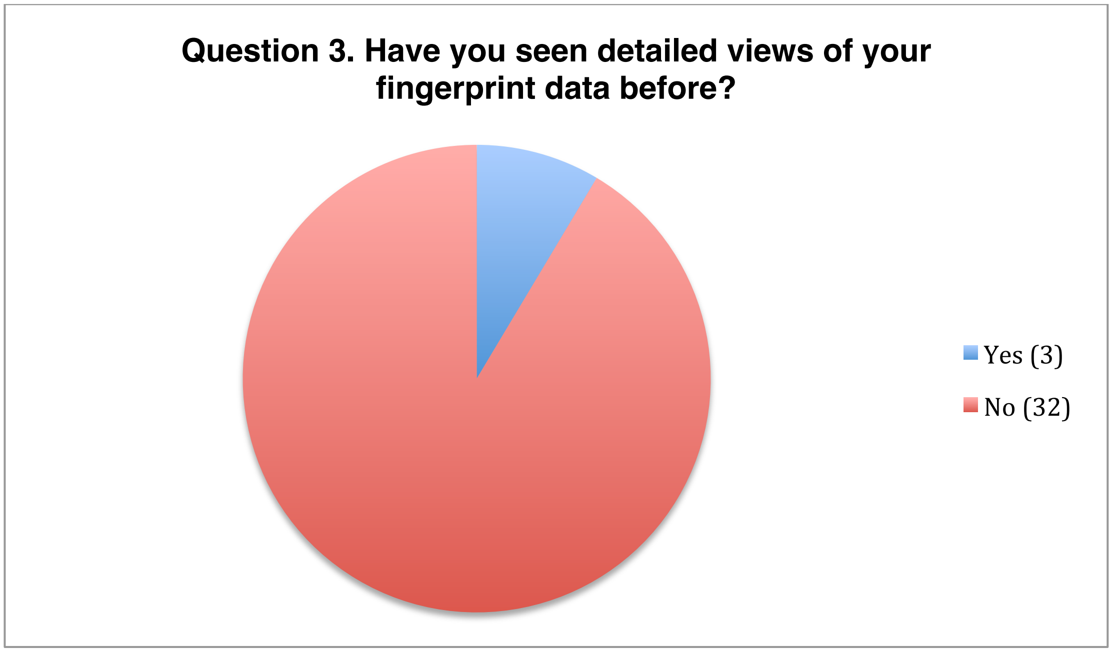
5.9.2. User Evaluations

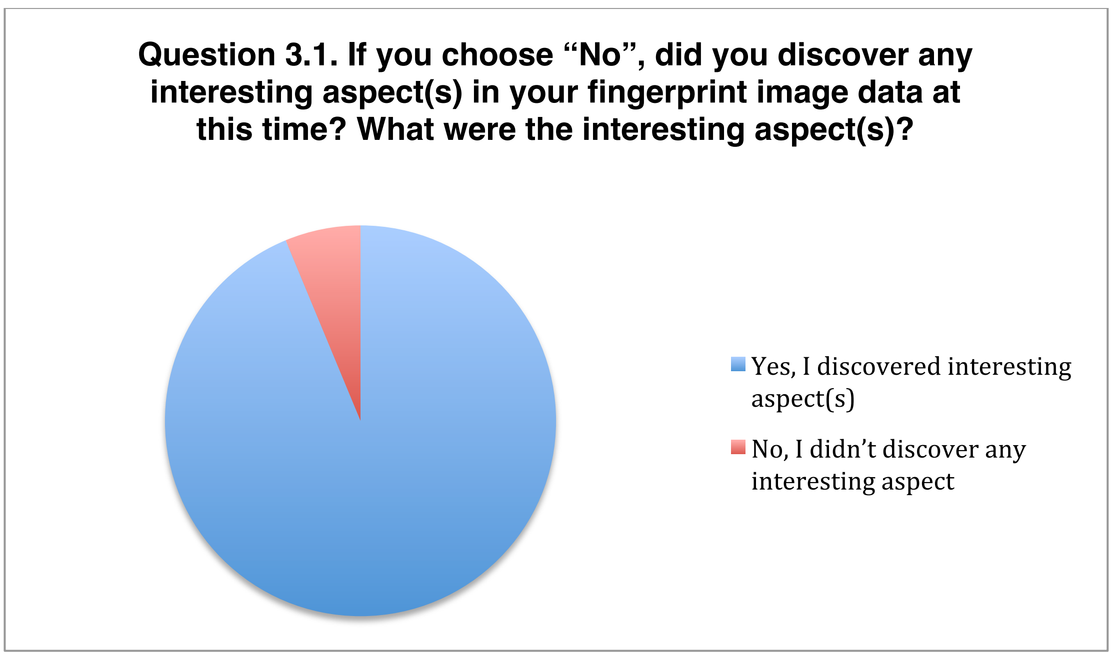
In order to examine how each participant experiences unique interaction with their own fingerprint data, user evaluations were conducted. The purpose of the user study was to evaluate how each participant has a unique experience with "Digiti Sonus." The artwork was installed in various locations such as the labs, offices, and hallways of buildings on the UCSB campus. Also, some user evaluations were conducted during the L.A.S.T. Festival exhibition at Stanford University in 2015. The artwork included a custom-made interface with a fingerprint sensor, a projection and a set of speakers/headphones. Participants could stand or sit on the chair and experience the artwork. First, they needed to put their finger on the fingerprint sensor. Once the image data was scanned by the sensor, it was transformed into a 3D manipulated fingerprint image and audio output. The user could then begin to experience the audiovisual results by using a touch screen or a mouse. They could also explore various audiovisual results driven by other fingerprint data, and compared them with their own results to discover the differences between them. After they fully experienced the artwork, they answered a simple questionnaire. The total duration of the user study was about 20-30 minutes including the setup, preparation, complete artistic experience, and answering the questionnaire. A total of 35 participants were included in the user study. The user group consisted of 20 male users and 15 female users, and the average age of the participants was 26.7 years old. The user evaluation was conducted in the University of California, Santa Barbara. (ORahs Protocol No. 3-15-1022, Title: Creating personalized media art experiences using biometric data) The final results of each question are listed below:




Question 1. Have you ever seen or experienced an artwork(s) using biometric data, especially fingerprint data before?
Yes (21)
No (9)
I don't know (5)

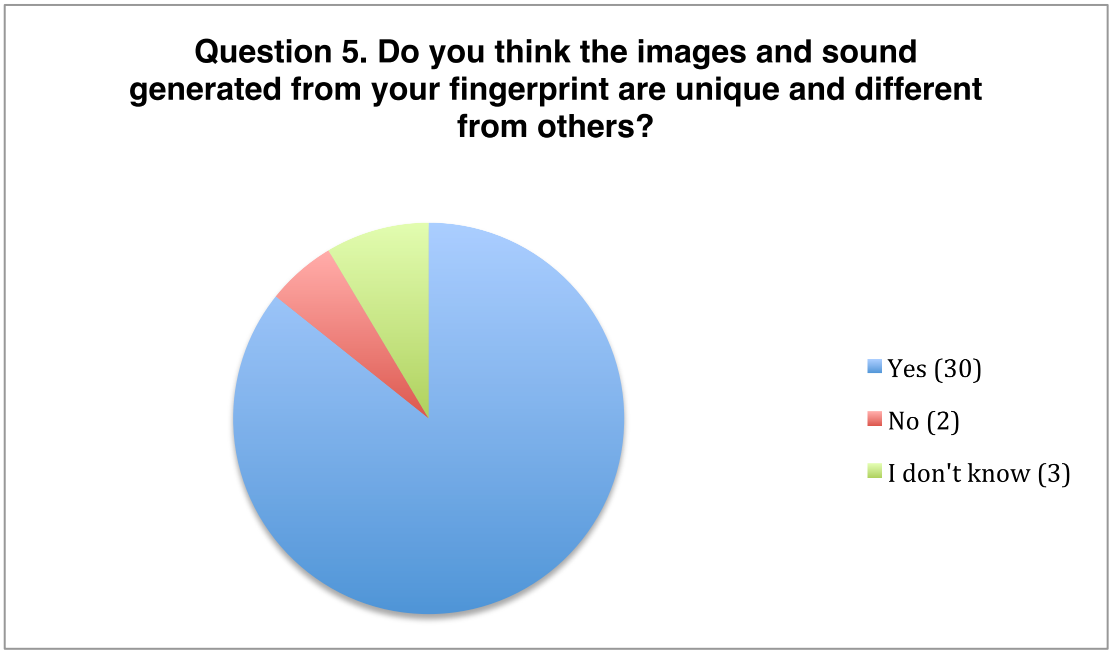

Question 2. Each individual has a different fingerprint and it does not change over time. Do you think this artwork delivers unique experience to you because of the use of the fingerprint?
Yes (32)
No (2)
I don't know (2)

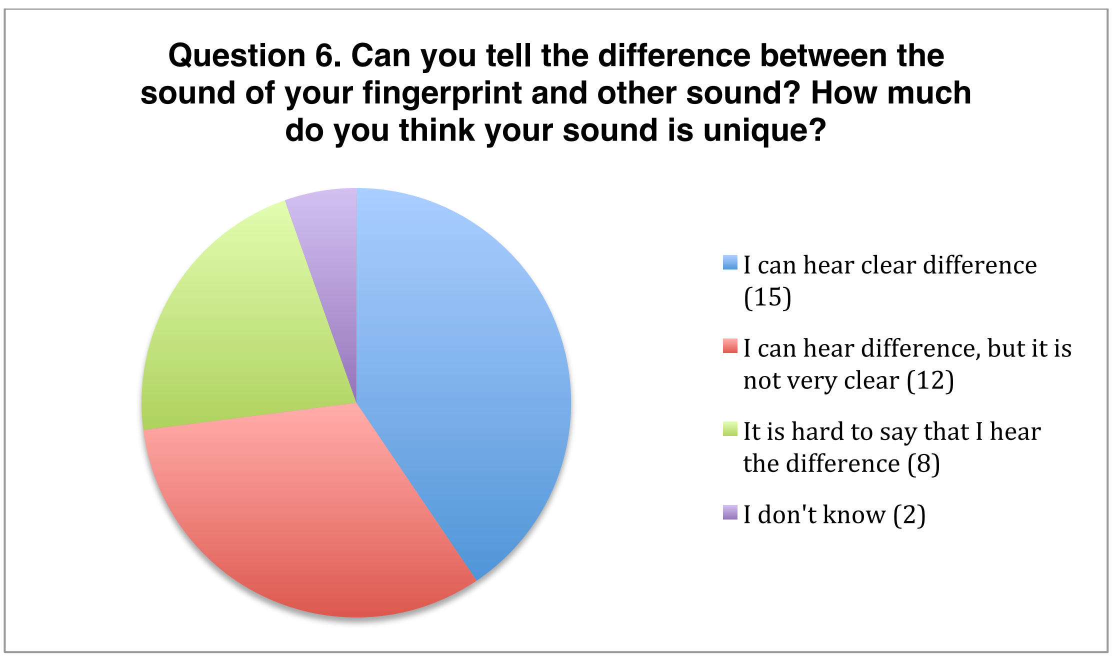


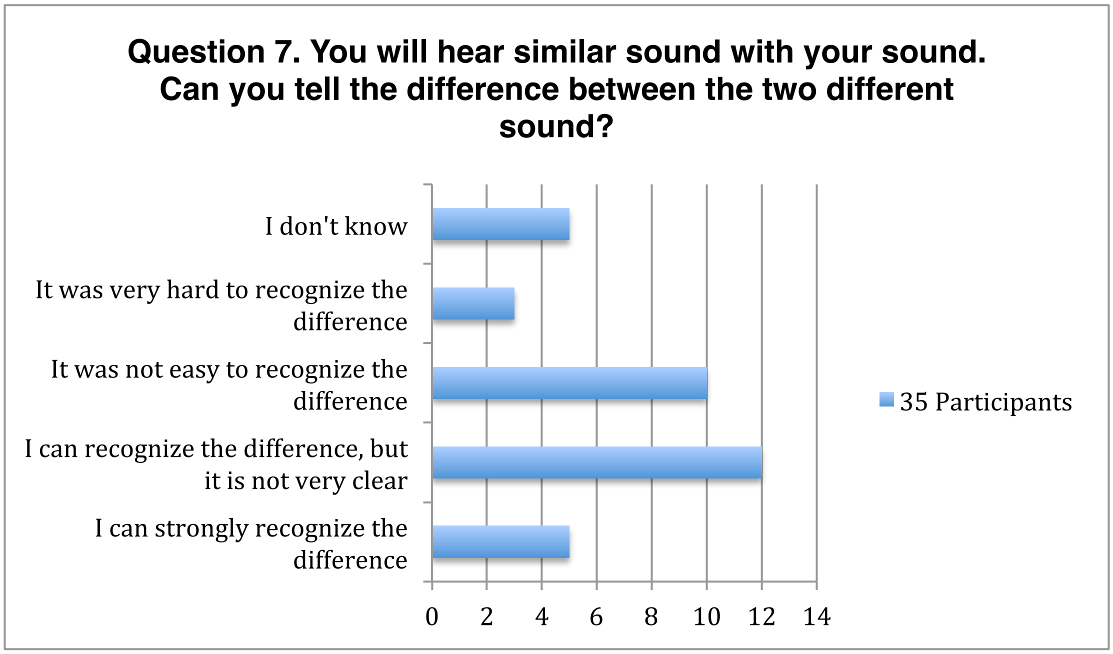


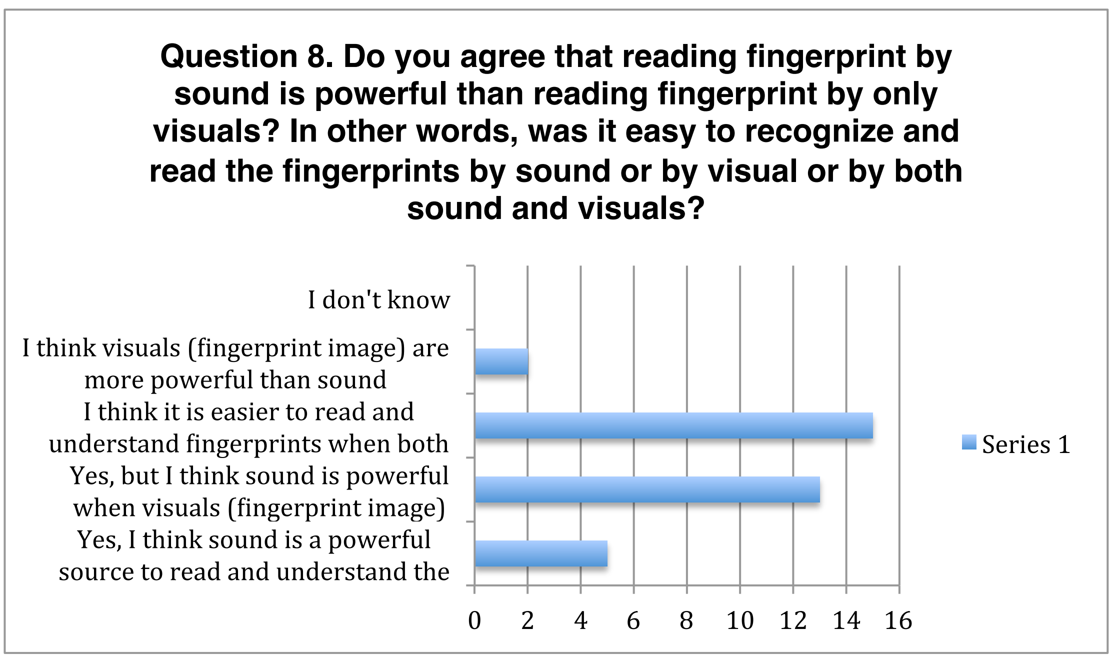
Question 4. How can you describe your perceptual experience in this artwork? Please describe and articulate your experience here. You can describe emotional

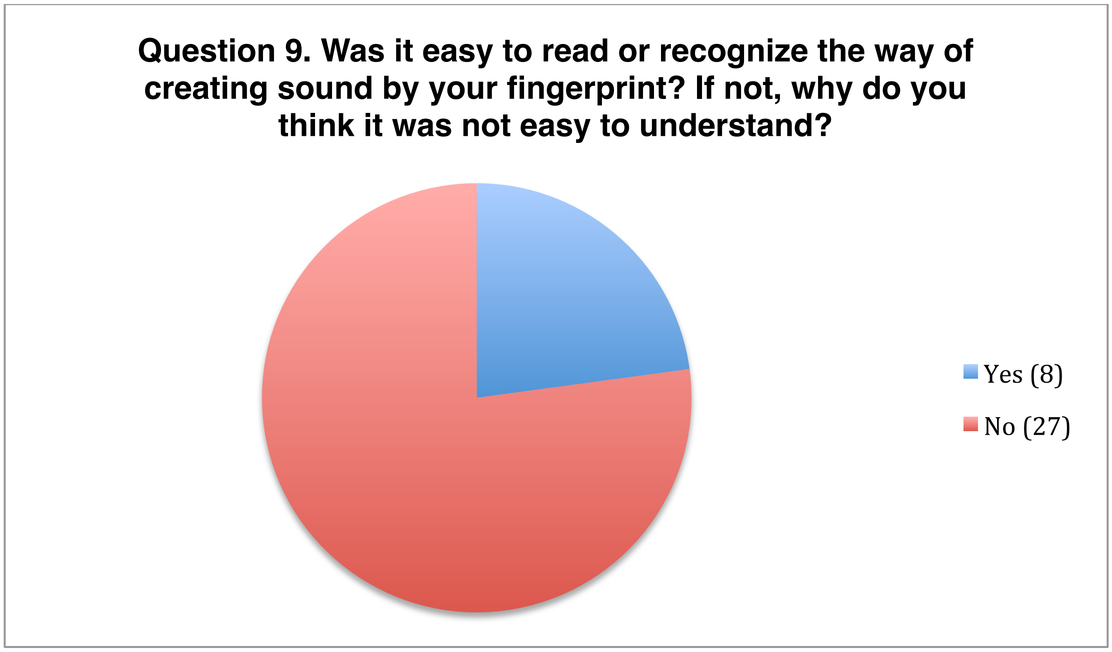
experience, or information you acquired from this artwork.





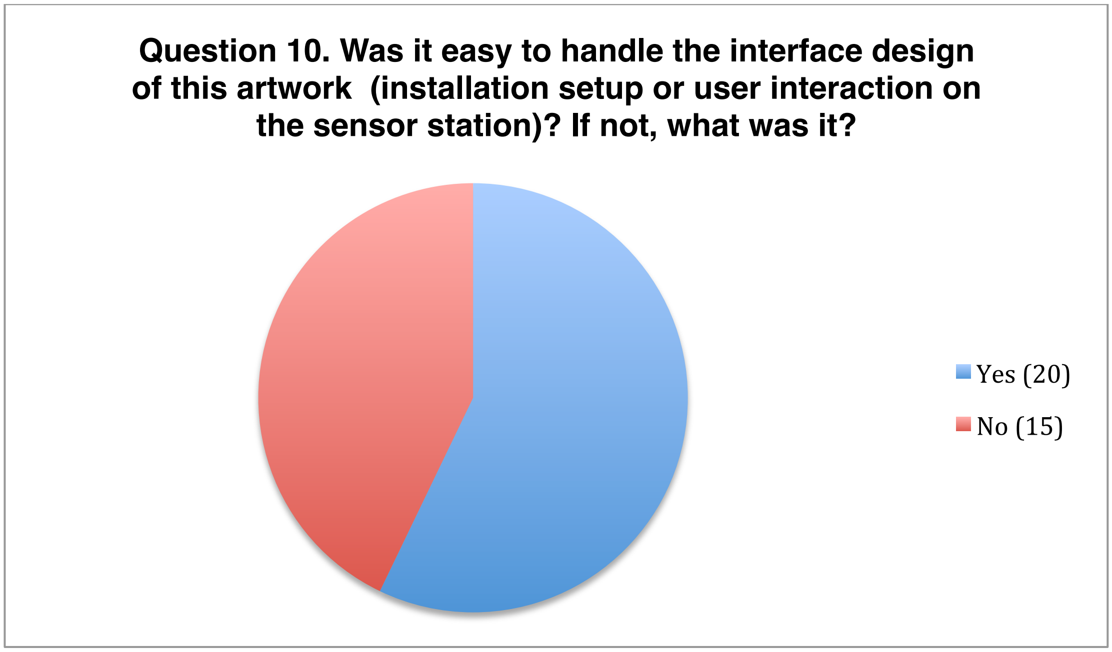

Question 7. You will hear similar sound with your sound. Can you tell the difference between the two different sound?
I don't know
It was very hard to recognize the difference
It was not easy to recognize the difference
I can recognize the difference, but it is not very clear
I can strongly recognize the difference
0 2 4 6 8 10 12 14
35 Participants


Question 8. Do you agree that reading fingerprint by sound is powerful than reading fingerprint by only visuals? In other words, was it easy to recognize and read the fingerprints by sound or by visual or by both sound and visuals?
I don't know
I think visuals (fingerprint image) are more powerful than sound
I think it is easier to read and understand fingerprints when both
Yes, but I think sound is powerful when visuals (fingerprint image)
Yes, I think sound is a powerful source to read and understand the
0 2 4 6 8 10 12 14 16
Series 1



Reasons:

- Unclear Interaction (10)
- Lack of Information on the screen/installation site (11)
- Hard to recognize the connection between visuals and sound at once (3)
- Others (3)



Reasons:

- Installation setup was unclear (4)
- User interaction on the sensor station was unclear (4)
- Sensor station was hard to navigate (3)
- Hard to recognize the connection (4)

The result of the user evaluations showed how much participants understood their personalized artistic experience, interactions, system of the artwork and comparison between fingerprint data. The results showed that almost 90% had fully unique experiences (Question 2) and they thought the visuals and sound of fingerprint clearly differentiate their fingerprint and other people's fingerprint. Considering the background and previous experience of the participants, they were new in this field and audiovisual experience in arts and most of the participants were highly engaged in this artwork (Question 3-1.) However, some users considered sound with other similar fingerprints is not clearly distinct (Question 6 and 7) Furthermore, 42% were confused with the details of the interactions and interface design due to various reasons (Question 10)

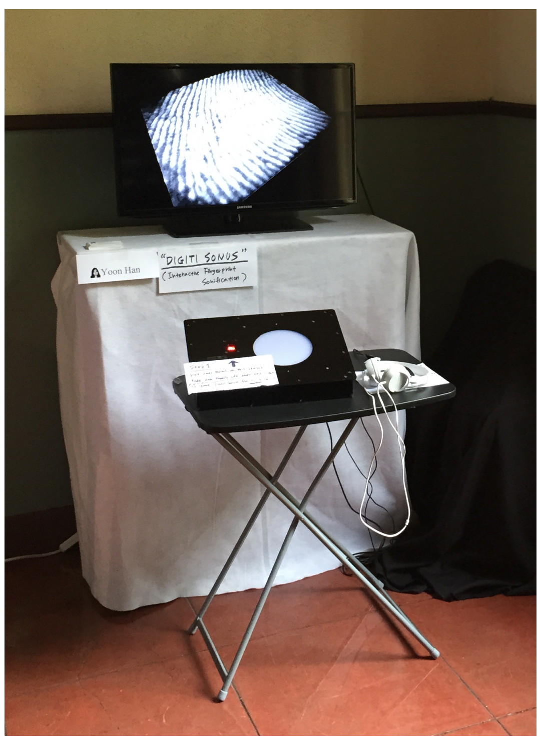


Figure 5.9.1: An installation set up for an user evaluation at L.A.S.T Festival in the Stanford University on October 2015

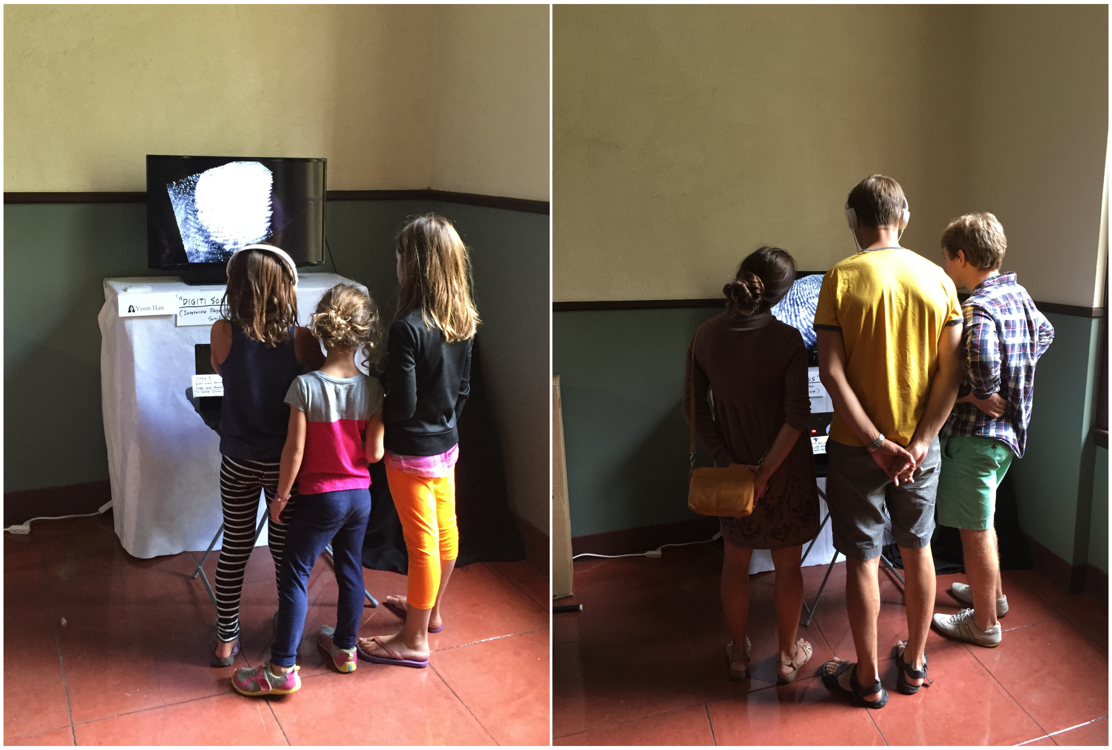


Figure 5.9.2: Several Participants Experiencing Digiti Sonus in L.A.S.T Festival

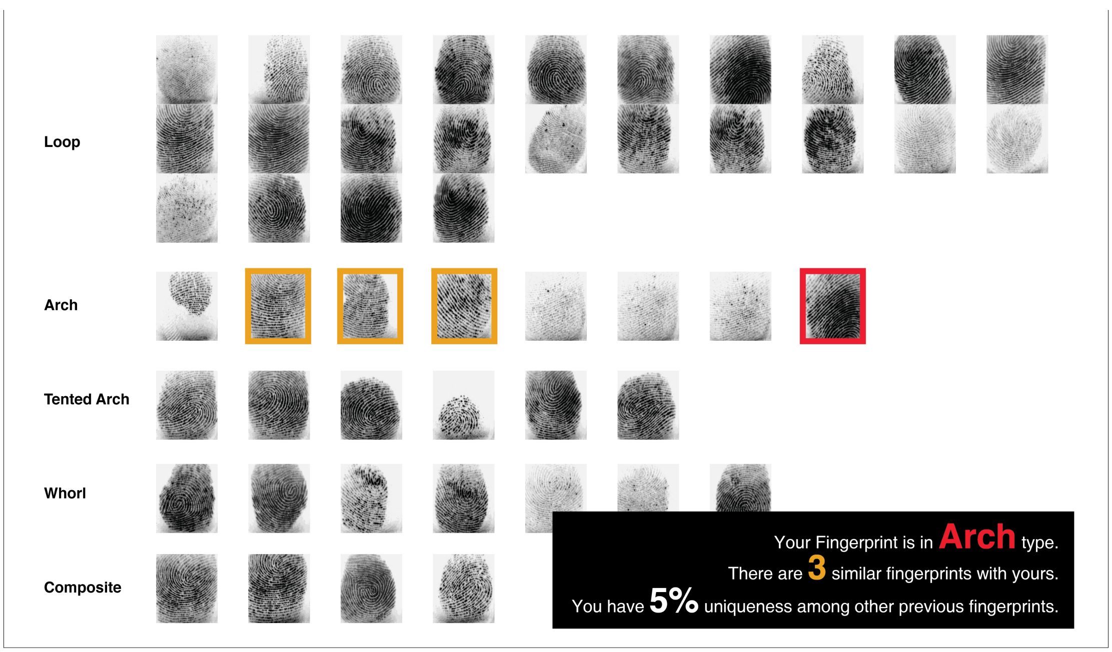
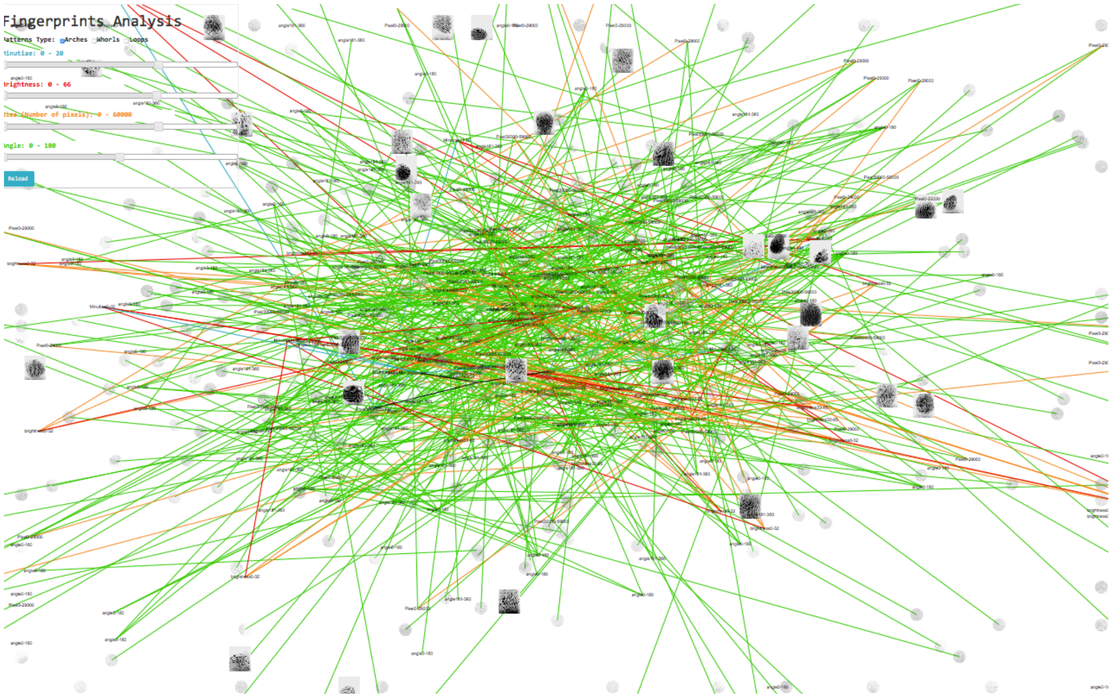
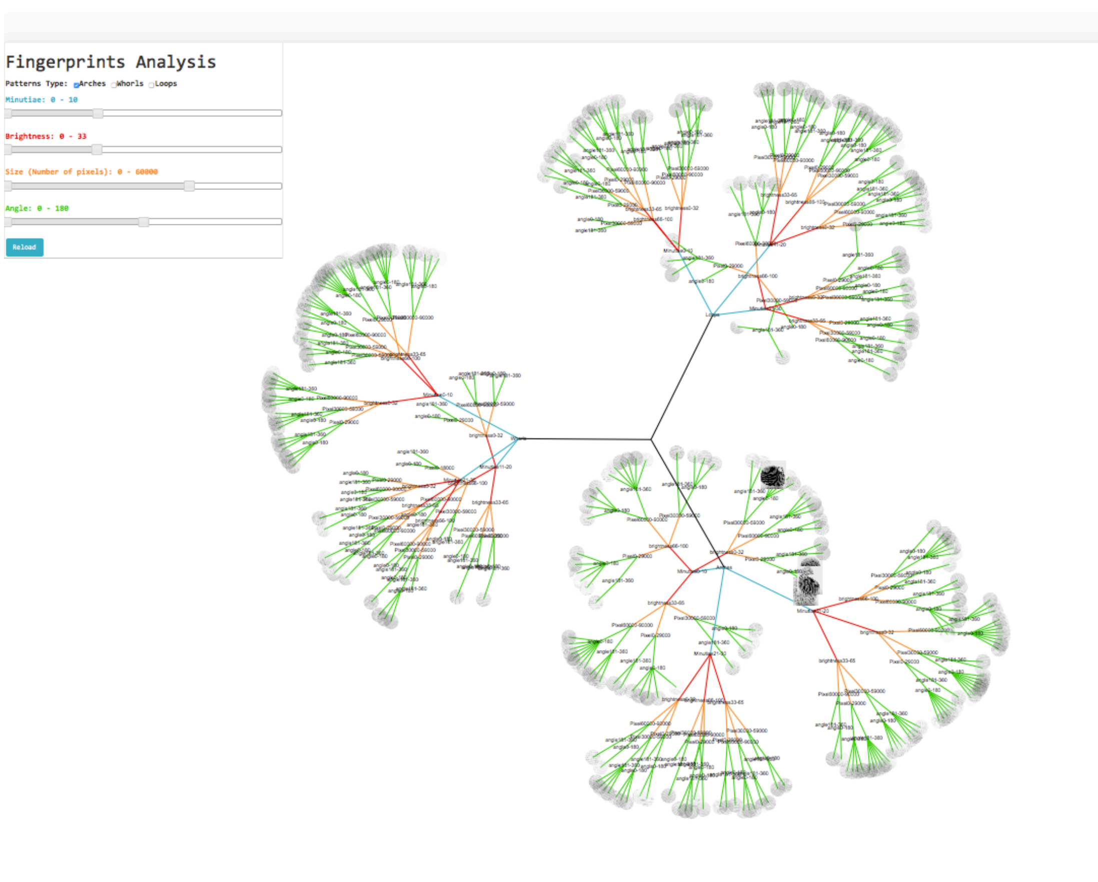


Figure 5.9.3: A Prototype of Fingerprint Analysis based on User Evaluation Results

After collecting all the fingerprint images, user evaluations and answers, a simple data visualization to analyze the results of the fingerprint images is created. The results of this data visualization are visualized based on on tree map structure with multiple branches as seen in Figure 5.9.4. There is a User Interface (UI) section at the top-left corner of the screen that let users select fingerprint images based on the types of patterns and other visual features. Selected images of fingerprint show in full transparency and deselected images are half-transparent. Users can also hover each image and read more detailed information about the fingerprint. This visualization was implemented using D3.js JavaScript library. (D3.js)


Fingerprints Analysis
Reload


Fingerprints Analysis
Patterns Type: Arches Whorls Loops
Minutiae: 0 - 10
Brightness: 0 - 33
Size (Number of pixels): 0 - 60000
Angle: 0 - 180
Reload

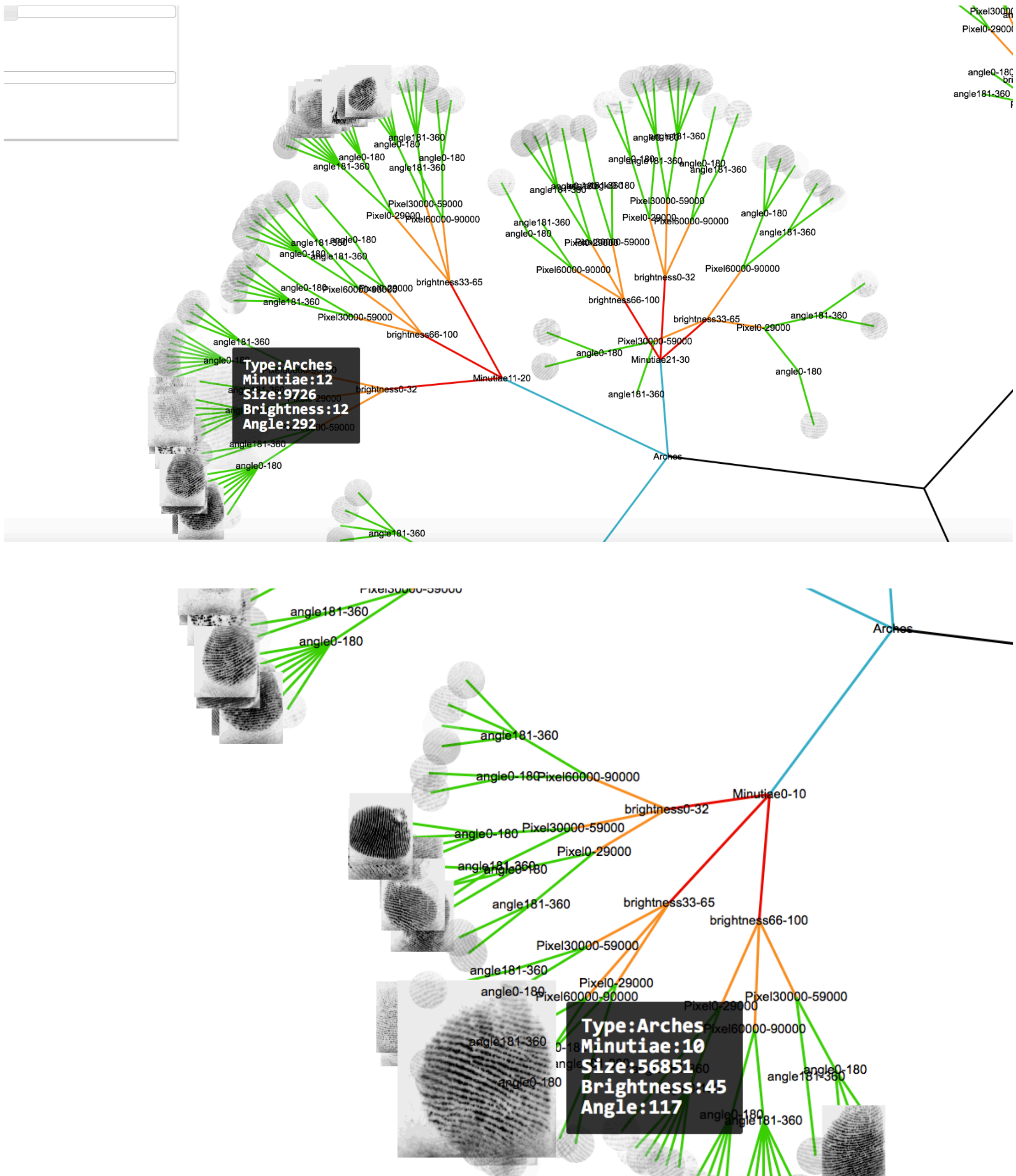


Figure 5.9.4: Screenshots of Data Visualization to Show the Results from the User Evaluations

More Informal User Studies based on Theories of the Hand Analysis

After learning about the hand analysis and personal narratives behind the fingerprints, I conducted an additional informal user study with 12 participants. This user study was based on the theories of the hand analysis that could read personalities and life goals of participants through the analysis of fingerprints (pattern type and locations). Even though this hand analysis is not a scientific research (almost pseudo-science), I see it has a value to check due to its long history of previous researches and applied practices that cannot be ignored when considering narratives of fingerprints in diverse perspectives. The procedure of this user study was similar to the previous user study I conducted. Total 12 participants experienced the artwork, Digiti Sonus, by seeing their fingerprints and hearing its sound, and answer questionnaires afterwards. At this time, I collected all five fingerprints from each person as the hand analysis requires all five fingerprints. After then, I followed these steps based on the book of a hand analysis (Coburn, 2008):

Step #1: Identify Your Own Fingerprints

Step #2: Fill in Your Fingerprint Chart

Step #3: Assign Points to Find Your High-Ranking Fingerprints

Step #4: Decode Your High-Ranking Fingerprints for Your Life Purpose

The questions were based on the criteria of the hand analysis. The participants ranked their fingerprints based on the instructions and sample charts as seen in Figure 5.9.5 (Coburn, 2008):

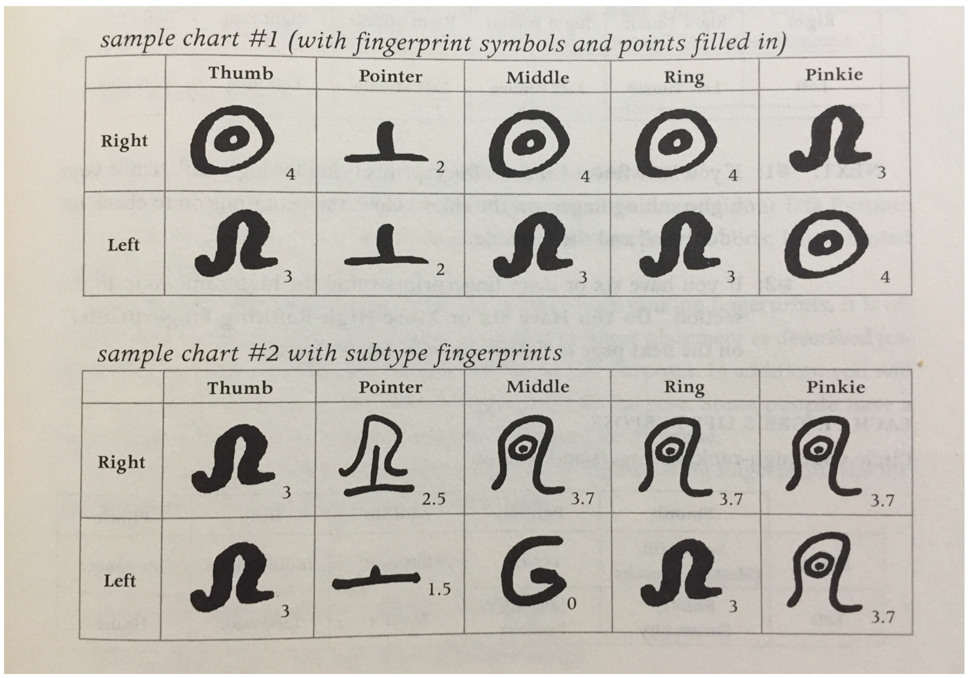


Figure 5.9.5: Sample Charts of Types of Fingerprints (Coburn, 2008)

For example, the participant 1 had arc type of fingerprint on his thumb, which means that he had higher rate on “Thumb: Results” of your life. This means that he has to read “Master of Results (Success). The questions asked to verify if he would consider having the personality himself. Participant 2 had whole type of fingerprint on his ring finger, which lead a hypothesis that he may be “Artists/Individualist.” The same questions were asked to the participant 2 to verify it. A half of the participants agreed with the results and analysis, however the other half of the participants were confused or did not agree with the outcome. It is hard to tell that this evaluation shows sufficient and reasonable results that the fingerprints could tell the hidden narratives well, however it was meaningful to find a possible way to categorize the fingerprints by both the visual features of the fingerprints and the narratives of the personhoods itself.

5.9.3.Exhibitions and Presentations

Digiti Sonus was selected for many international exhibitions and presentations. (a list of the selected exhibitions, presentations and participated conferences are included in Appendix. B) In this section, the installations of Digiti Sonus in different spaces and environments for various exhibitions and its results are discussed.

5.9.3.1.DaVinci Exhibition

The first version of Digiti Sonus was supported by DaVinci Media Art program from GeumCheon Art Space in Seoul, South Korea in 2012. It was the first moment to develop both artistic concept and technical implementation and the work-in-progress versions show various steps of developing the project. Due to the shape of the finger thumb, the projection plate was created as an oval shape. Three projections show the same three-dimensional images in different perspectives, thus the audience can observe the animated fingerprint image in various positions.

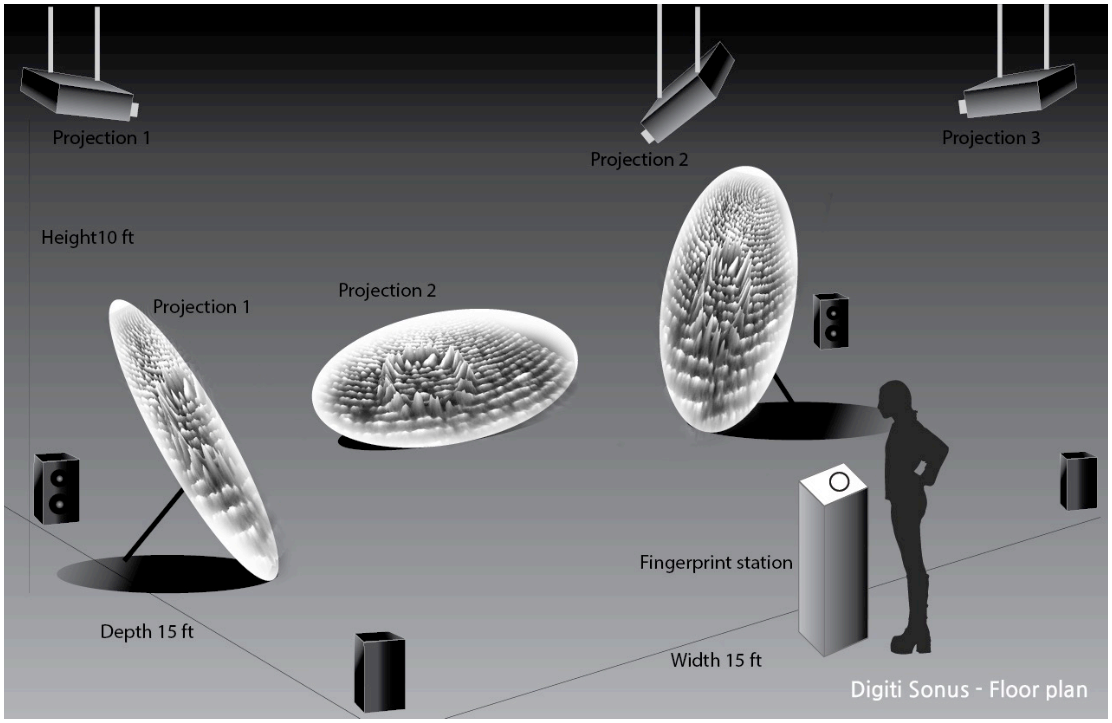


Figure 5.9.6: A Floor Plan of Digiti Sonus V1

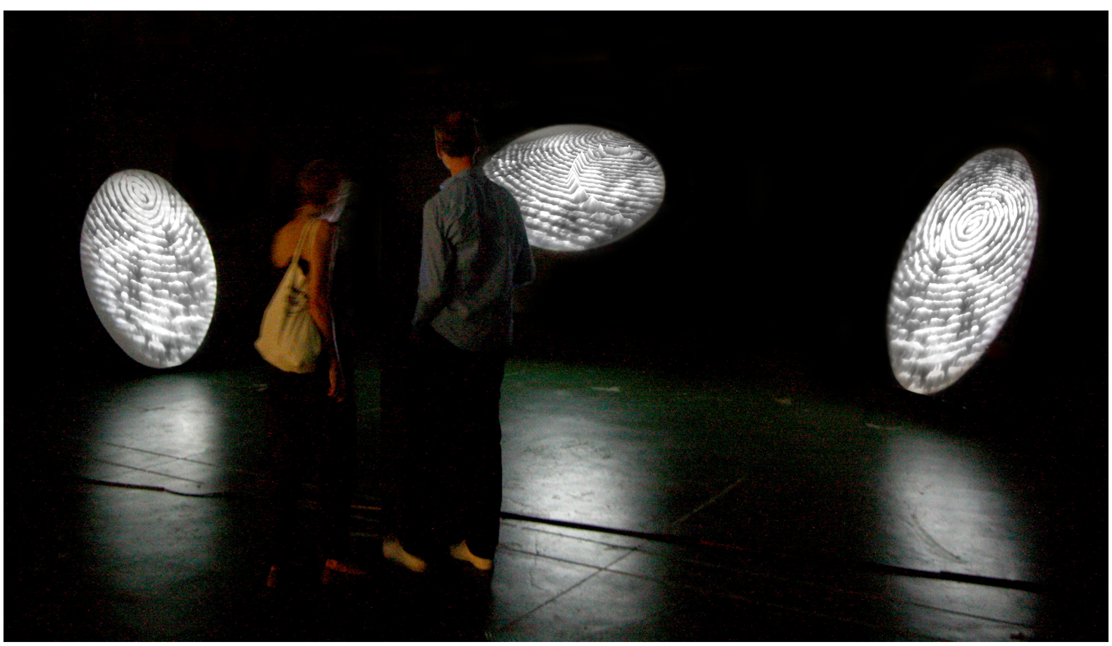


Figure 5.9.7: An exhibition view of Digiti Sonus V1 at the Geuncheon Art Space

5.9.3.2. SIGGRAPH 2013 Art Gallery

Digiti Sonus was exhibited at the SIGGRAPH 2013 Art Gallery at California's Anaheim Convention Center. The floor plan and exhibition setup were largely similar to the previous installation in the Geumcheon Art Space, but the two changed parts in the gallery setup were its lighting condition and an open space for the exhibition venue. The gallery was a bright space, which caused a lack of attention on the participants' part, even though the projectors were bright enough. Due to the open environment in the convention center, there were no walls to cover the given space for this installation as an open space. Because of the conference's size, a larger number of participants visited and experienced this artwork and left a lot of comments and feedback.

Figure 5.9.8: An Exhibition image of Digiti Sonus at the SIGGRAPH 2013 Art Gallery

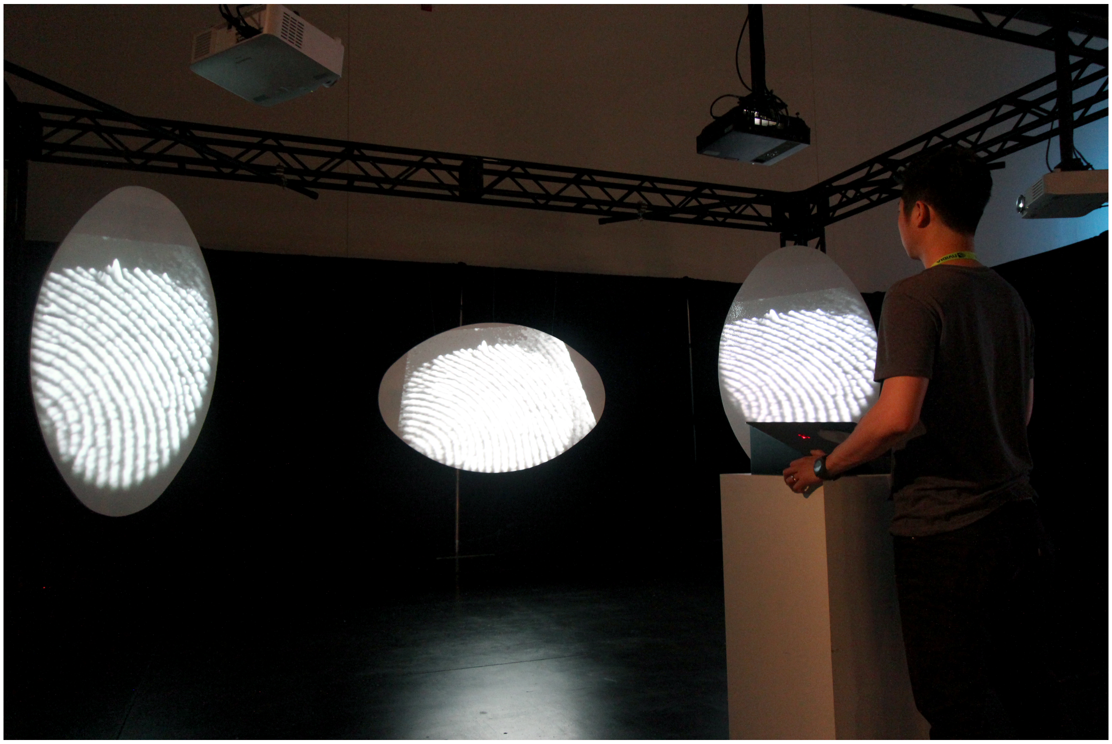


Figure 5.9.9: An Exhibition image of Digiti Sonus at the SIGGRAPH 2013 Art Gallery

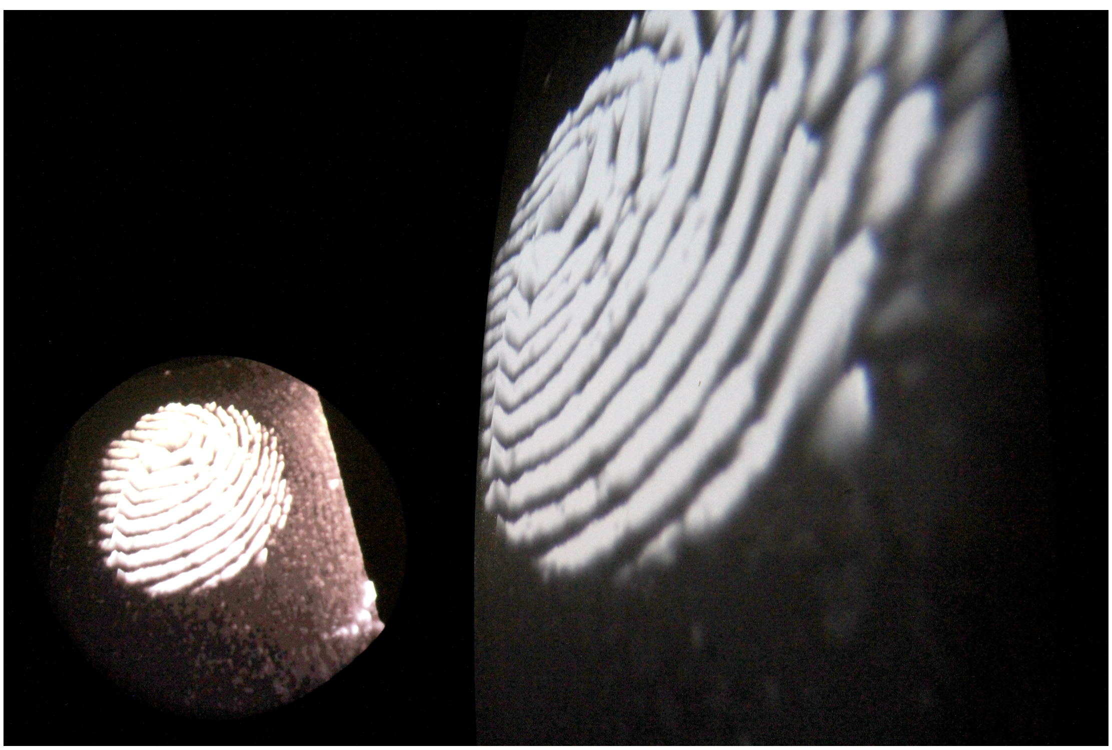


Figure 5.9.10: A close-up image of Digiti Sonus at the SIGGRAPH 2013 Art Gallery

5.9.3.3. "Hybrid Highlights" Exhibition at the SNU MOA

Digiti Sonus v2 was exhibited at Seoul National University's Museum of Art in South Korea in 2014. It had one projection and one fingerprint interface. Section 5.8 describes details of Digiti Sonus v2, noting that a group of images of a fingerprint are saved and users can select one of them to explore details of the audiovisual content, then compare this with his or her audiovisual results with the others.

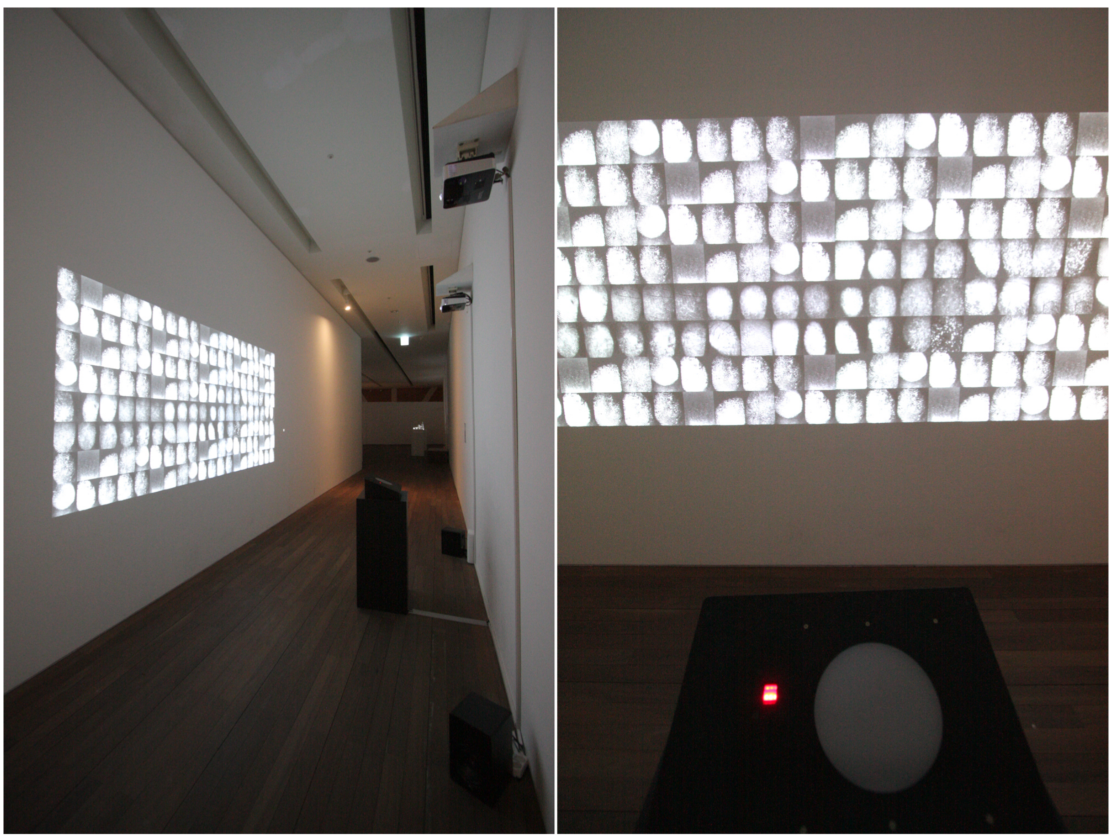


Figure 5.9.11: Exhibition images at the Museum of Arts in Seoul National University

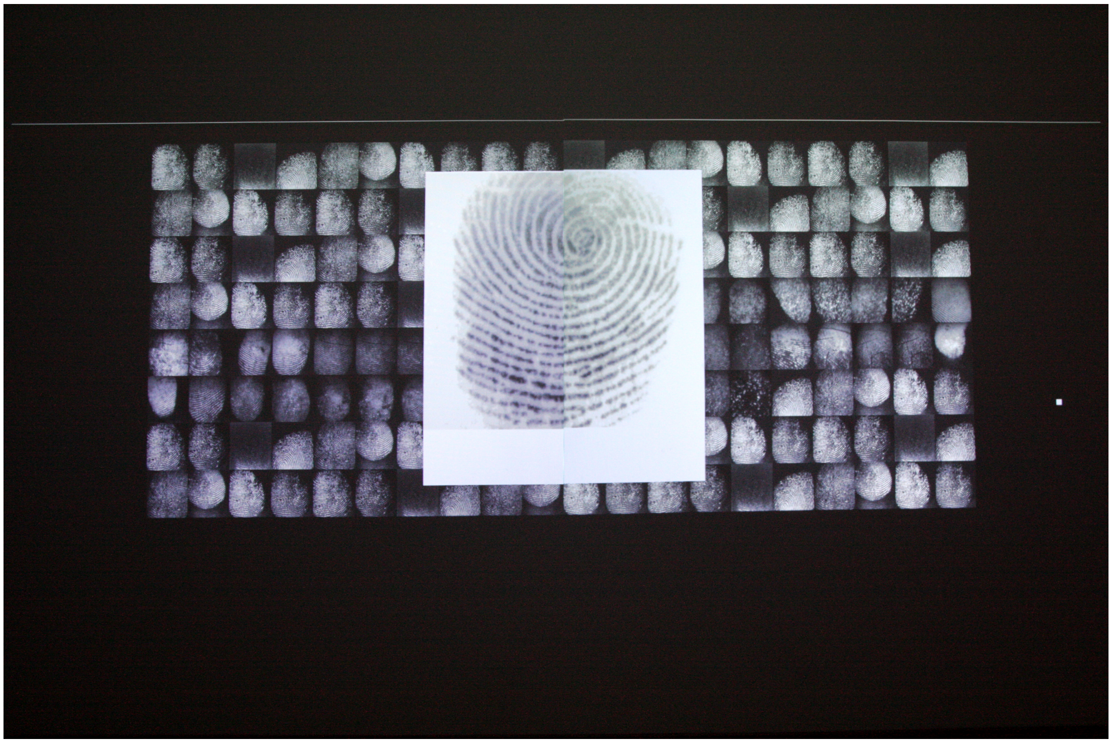
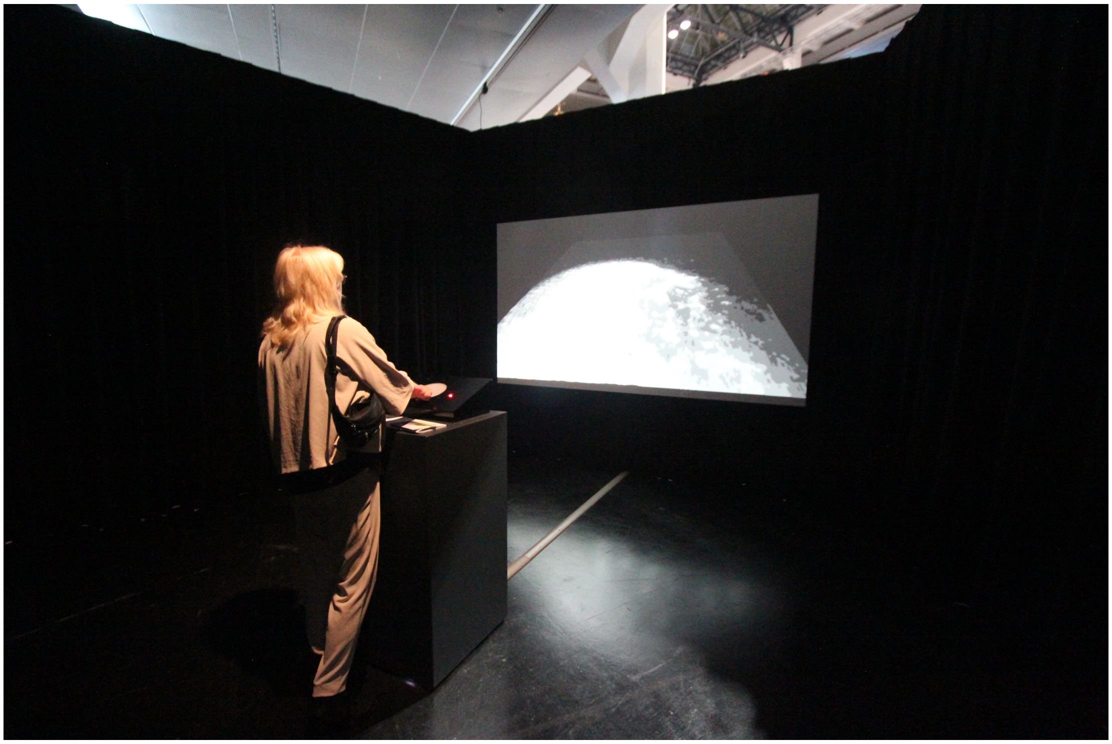


Figure 5.9.12: A Detailed view of Digiti Sonus at the Museum of Arts in Seoul National University

5.9.3.4. GLOBALE: Infosphere at the ZKM Museum

Digiti Sonus was exhibited at the exhibition GLOBALE: Infosphere at the ZKM museum in Karlsruhe, Germany, in 2015. It had one projection and one fingerprint interface in a closed room. The space was completely dark, which enhanced the readability of the projection image. The audience could have a more immersive experience in the enclosed space. The exhibition was peer-reviewed and invited by curators at the ZKM museum. A detailed review of the artwork from a curator is in Appendix C.



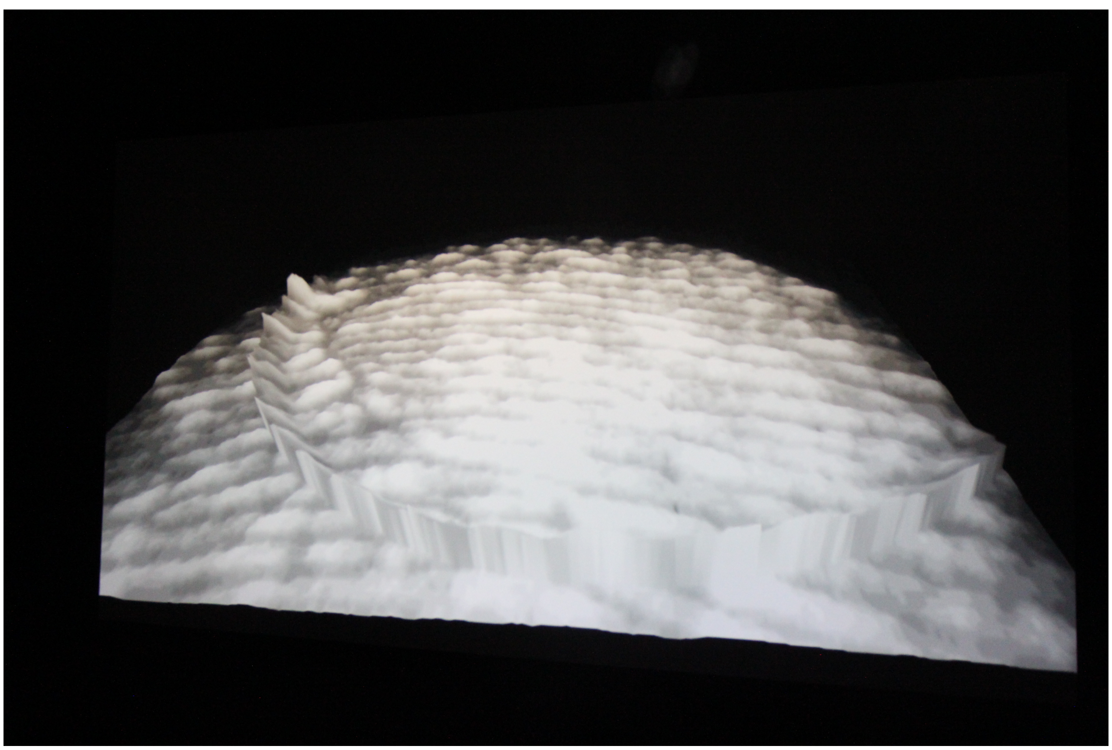


Figure 5.9.13: Exhibition images of Digiti Sonus at ZKM, Germany

Chapter 6

Conclusion and Future Works

6.1. Challenge and Significance as Art

Digiti Sonus is an interactive multimodal artwork generating distinct audiovisual results for each audience member using their fingerprint data and other personal information. The main goals of the artwork and the research in this dissertation are to investigate in-depth narratives using the biometric data and to explore how this content can create a link between an artwork and its audience by causing the audience members to become deeply engaged with the artwork through their own stories. To achieve these goals, biometric data, specifically, fingerprint was used to generate input material for the artwork for personalization. Due to the unique visual features of the fingerprint image data, each audience member could receive different audiovisual results. According to biological science, even though the fingerprint data is created by genetics, the patterns are almost randomly generated. Similarities within families exist, but every person has a unique fingerprint. In order to make the fingerprint data more meaningful, we connected our analysis of biometric data to historical, cultural, and interactive models. These represent broader narratives about biometric data. Some of these models are ironic, which is where much of art functions. In effect, we re-purposed the scientific data and recast it within a context of these models.

In Digiti Sonus v1, one weakness was the lack of a grouping system that related fingerprint patterns to one another. When experiencing Digiti Sonus v1, each individual wondered what group they would be associated and how they would relate with other audience members. They wanted to learn how the sound was generated from their fingerprint data. A system of collaborative artistic experience was needed. In order to solve these issues, Digiti Sonus version 2 focuses on exploring new ways of reading and experiencing both the individual audiovisual results and other participants' audiovisual results. All the fingerprint images are collected, grouped together, and each participant could understand how his or her own results can be associated with others. Furthermore, in addition to the visual features of the fingerprint data, I gathered each person's basic information to investigate the association of groups based on the user survey and an analysis of their fingerprint pattern. Thus, creating personalized artistic experiences for users is now possible.

Compared to the original version of Digiti Sonus, available user interactions and grouping system in Digiti Sonus v2 should help users better understand the unique characteristics of the fingerprint. In order to measure the effectiveness of the grouping system, I conducted user studies to check how participants understood their personalized artistic experience, how they understood the interactions and the system of the artwork, and how they compared to other users. The results showed that almost 90% had fully unique experiences and they were satisfied with the results, which proves the value of my hypothesis. They especially liked the fact that they could magnify the fingerprint image and see it visualized nodes within a systemic whole. Furthermore, this newer version used a hand motion technique using camera sensing technology to enhance the flexibility of interactions (Han, 2015), and moreover this hand motion created the opportunity for a broader range of options for controlling images, providing greater freedom than with other physical interfaces (e.g. mouse, keyboard, or joystick). Using this new approach, we have observed that vast majority of users are enthusiastic during participation with our installation.

The presence of the user as one component within a collective grouping system is achieved through image sensing technique and voluntary interaction. Although the fingerprint data does not describe the person, it is unique and thus personal. This unique personal connection enables another richer information and relative associated narrative experience through it, with visual feature grouping analysis. The basic personal information and users' opinions on the artistic experiences truly personalized artworks. The results showed how the fingerprint data could not be the same with the randomly generated identified numbering system. It definitely has meaningful information that could tell the unique features and complex details of encoded visuals, which was expanded more with the participant's input and preferences and opinions.

This research proposes that this approach is a novel and suitable method for artistic manipulation of fingerprint data, especially for transforming fingerprint data into sound. It creates more personalized and unique multimodal media art experiences, which has to our knowledge not been previously attempted in the fields of media art/design. Compared to existing biometric-based artworks such as DNA art, Digiti Sonus uses more dynamic 3D visuals controlled by users, and have multimodal interaction that leads unique experience for each audience member. Although previous biometric-based artworks can only observe non-interactive, single image generated by one person, Digiti Sonus can be modifiable by users interaction and compared with other fingerprint data through grouping system. Therefore, Digiti Sonus v2 is a model for creating personalized art, while providing a thought-provoking stimulation and multimodal interaction experience for the user.

6.2. Future Directions

Digiti Sonus is an ongoing project. There still remain many challenges that need solutions regarding both the artistic approach and technical development. Even though I conducted user evaluations and received evaluations from curators, this project is still difficult to compare with previous fingerprint-based artworks due to a much lower number of fingerprint-based interactive artworks and fewer critical investigations. Deeper research on various perspectives of this Digiti Sonus project should continue.

A fingerprint contains an almost infinite amount of unique data, but it is challenging to collect the enormous amount of fingerprint image data as an individual artist due to privacy and security issues. Without any support from government agencies or collaborations with research centers in biometrics and related fields, it is impossible to access the data to test my hypothesis and the applications to generate audiovisual output. Compared to the big data, the fingerprint data I collected from the user evaluations and previous exhibitions are much fewer in number. Due to the weaknesses of the statistical data, it is hard to generalize the decisions about the different characteristics of different groups of fingerprints. In future studies, it is necessary to access enough fingerprint data to conduct a higher number of user evaluations to increase the accuracy of the test results.

Digiti Sonus needs more advanced features in the grouping system. As a collective art form, each fingerprint datum can be transformed into an artificial identity/organism that possibly exists in a virtual world and communicates with other agents for more open-ended interactions within a more detailed world-making system. Furthermore, it needs more options and controls to modify groups based on more diverse features.

Furthermore, other biometric data such as retinas, faces, or earlobes can be applied to examine whether or not fingerprints are the most unique and effective source for this project. Additional biometric data will also open up more diverse approaches and methods to convert the data into artistic materials. Different visual features of different biometric data will broaden the potential for creating more personalized artworks for each audience member. Multiple biometric data may lead to more interesting results, engaging the audience through various multisensory experiences.

Nonetheless, powerful technology should be used efficiently to enhance the quality of the audiovisual results and user interactions. In terms of hardware set-up, the ZFM-20 fingerprint sensor reads images in low resolution; the reading speed is not fast enough. A more advanced fingerprint sensor with higher resolution and speed should be researched; it will improve the quality of the visuals and sounds, and enhance users' overall experiences. A more powerful computer with a higher GPU will enhance the faster speed and the higher quality of generating dynamic 3D fingerprint images instantly. Digiti Sonus v2 used 50-60 fingerprint images at a time due to the limited computer GPU. A higher number of 3D animated images on the screen at one time will be possible using a higher GPU.

Digiti Sonus is compatible with many different mediums, including mobile devices, web browsers, indoor and outdoor installations, and projection screens. Using various fingerprint sensors on many different devices will increase the accessibility of this artwork for many people, and open the possibility of creating new artistic developments.

Some audience members of previous art exhibitions asked about the possibility of collecting their own fingerprint images with sound after the experience. One possible future works could be an optional feature for exporting and printing 3D fingerprint images or sound files for each audience member who prefers to collect the result as a physical object. This will not only be an interesting approach to creating personalized physical output, but will also extend the audience's artistic experience beyond the gallery.

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Appendix

A.Artist Statement

For the past seven years, my principle interest in interactive art/design has been in exploring new multimodal experience using the human body data and audiovisual components. I have investigated the new ways of visualizing sound and sonifying visuals in many different forms such as interaction design, data visualization/sonification, interactive art installations and sound visualizations. Even though I was trained as a graphic designer and visual artist, I kept noticed "sound" is everywhere, invisible, intuitive and experiential. These characteristics of sound led me to keep creating the diverse ways of expressing sounds based on my intuitive thoughts and observation of human's behaviors. My sound interfaces focused on combinations with sound, color and physical body interactions. Synaesthesia was a main concept of my interface design, which investigated the relation between color and sound under the mathematical system that allowed people to create harmonics and regular rhythm easily. I also concentrated on generating the improvised sounds by electronic sensors, computer programming, and physical devices to amplify the boundary of human's hearing organs. My works also have explored the tactual and analog materials to cover digital technology.

I was inspired by works of Nam June Paik, Toshio Iwai, John Cage, Oskar Fischinger, John Whitney, and John Maeda's simplicity. Nam June Paik's works focusing experiments of media, culture, and materials were the foundation of my works toward seeking the new media methods. John Cage's de-montage of music and musical notes leaded her to experiment and deconstruct the sound media and technology. Also, Oskar Fischinger and John Whitney's computer animation visualizing sounds and music delivered the inspiration of creating sound visualization in her own perspective. In particular, Toshio Iwai, who is the one of the most creative contemporary sound artists created interactive sound installations and physical devices which leaded me to find my sights about digital sound media and device. Also, I admire the simplicity rules by John Maeda as the basic principle of successful art and design. Through inspirations from those great contemporary media artists and designers, I created sound installations and physical interactions. "Harmonia (2008)," which focuses on the relationship between sound, color and basic shape objects was my best example that addressed new, easy and experimental musical instrument. If a user puts objects on the table, sounds (musical notes) are created with circular shapes around the objects. It shows the easiest way of generating musical sounds with multi-touch table and objects. One of my previous works, "Color note (2008)" is a projection-based sound installation, and it applies the human's movements to draw musical notes in public space as a random interactive way. I attempted to generate unexpected sounds by using human's walking on the street or hallway. One of my works, "Sound Marbles(2008)" shows the combination of digital technology and analog materials, and it reminds people of the aesthetic value of analog materials hidden digital technology and feel comfortable to get the context of media installation.

In 2011, I became obsessed with patterns of nature and the human body. I started investigating, magnifying and reorganizing biometric patterns, which contain a unique and microscopic world discovered in the human body, in order to explore new meaning of our identity and originality. I was consistently asking; what is the origin and meaning of biometric data, and how can it represent ourselves? What is the difference between our natural-born identities and our acquired identities throughout lives? And how can we discover our new identities through sensory interaction? These questions were the theme that runs through the last five years of her artistic practice.

In 2012, I created an interactive fingerprint sonification and presented the work “Digiti Sonus: An Interactive Fingerprint Sonification” in several international exhibitions and conferences. In artistic approach, Digiti Sonus showed how audience’s fingerprints could be transferred into sonic elements to bring new sensory experience, and it was exhibited in GeumCheon Art Space as a part of Media City Seoul 2012. And a paper “Digiti Sonus: An Interactive Fingerprint Sonification” was published on ACM Multimedia 2012 on October 2012 in Japan. Also, it was exhibited at Siggraph 2013 Art Gallery, and featured as a main cover of Leonardo Journal special issue.

The aim of this research was to have a series of framework that is illustrative of the potentials for sonifying human body patterns. Transforming those unique patterns into sonic results allowed audience to experience the discovery of sensory identities; from an artistic perspective, finding their own sound identities through the body patterns gives a unique multi-sensory, immersive, and unexpectedly unique experience to the audience. And visually impaired people can discover a new way of communicating with other people and identifying themselves with sonic results in socially practical and impact ways.

My approaches focus solely on the unique patterns of the human body allowing for a more detailed sonic description. Fingerprints, retinas, palm lines, and face are the materials of the series of this research. Each biometric pattern can be used for the focus of sighted people's interaction with one another. The lack of ability for partially sighted people to perceive the visual clues the face gives us, can lead to social problems and artistic-like behavior, which can solve by using another sensory medium – Sound. I believe that data sonification can serve as an effective technique for the representation of complex information like the human body patterns, due to the auditory system's ability to perceive stimuli at a wide spatial cover and its inclination to perceive spatial patterns in sonic input. Furthermore, sonification is successfully used in a variety of situations where visualization techniques are deemed inappropriate or insufficient. It allows people to gain an awareness of their environment without the need for visual interpretation. While the research is obviously intended for sighted people, the potential for helping and enriching the lives of those with difficulty seeing is equally obvious.

Interactive media artists are engaged in changing the relationship between artists and their media, and between artworks and their audience. They create relationship and system, which contains feedback between the interactors and the system, and need to create the highest indeterminacy and subjectivity in their experience. Many interactive media artworks are occasionally depersonalized since they have limited contents and lower number of scenario due to pre-determined input data or too strong constraints. Among many personalized data, "biometric data" becomes a good one because it is non-replaceable, non-changeable, and genetically hybrid data, which will create individually unique and authentic experiences to audience. I believe that such works are a promising method to suggest new communication and fulfill individual's desire to create artistic experiences and sensible beauty. As I have known, my research on biometric data sonification is new; there have not been previous research that transforms visual feature of biometric data to audio in both scientific and artistic approaches. In scientific and engineering researches, deep analysis on biometric data patterns itself have been conducted, however, it has never touched the sonic approach using the biometric data. Furthermore, in artistic field, using biometric data to create audio is rare. Thus, this research is possibly a novel, groundbreaking, and pioneer step on both biometric data sonification and personalized biomedia art.

Not only investigating biometric sonification, my ongoing projects also explore new haptic/virtual ways of integrating visuals, sound and human behaviors with many dataset such as urban data, social media data, and web data. Through the experiments in visualizing/sonifying the data and re-envisioning our environment within everyday life, my aim is to push people away from paradigmatic thinking. I keep trying to take new different approaches in retransforming analogic materials and common culture, and in subverting common perception of reality. By observing nature and human, I attempt to transform the complex system of big dataset into the digital domain in a compelling way. My works constantly articulate a tension between the visually intriguing patterns and the minimal audiovisual elements. Carrying multiple sensory depths, the aesthetics of emotional impacts in my minimal digital interfaces reverberate.

B. List of Exhibitions, Publications and Conferences related to this dissertation

Exhibitions

- L.A.S.T Festival “Digiti Sonus” Stanford University, CA USA
- ZKM Infosphere exhibition “Digiti Sonus” ZKM, Karlsruhe, Germany
- “Hybrid Highlights” “Digiti Sonus” Museum of Art, Seoul National University, Seoul, Korea
- “Davinci Creative 2014” “Virtual Pottery” Geumcheon Art Space, Seoul, Korea
- “Sonic Trace” The Second Solo Exhibition (supported by AliceOn), The Medium, Seoul, Korea
- "Daily Reflections" at Total Museum, “Digiti Sonus” Seoul, Korea
- "Digital Media" at Cal Poly San Luis Obispo, “Cloud Bridge” San Luis Obispo, CA USA
- IEEE VisWeek Art Program 2013 (Selected), Atlanta, Georgia, USA
- ACM SIGGRAPH 2013 Art Gallery “Digiti Sonus” Anaheim Convention Center, Anaheim, CA,USA
- MAT End of Year Show 2013, “Digiti Sonus”+”Cloud Bridge” Elings Hall, UCSB, USA
- “Things That Turn Your Brains To Mush”, Santa Barbara Contemporary Arts Forum

- “Tree Rings”+”Sound Tree Rings”, Santa Barbara, CA, USA
- Seoul Mecenat and ArtsWalk 2012, “Digiti Sonus” Seoul, Korea
- Renewed Memories - Media Art Created with Personal Retrospective,
- Arcade gallery, San Pedro, CA, USA
- Media City Seoul 2012 DaVinci Exhibition, Geumcheon Art Space, Seoul, Korea

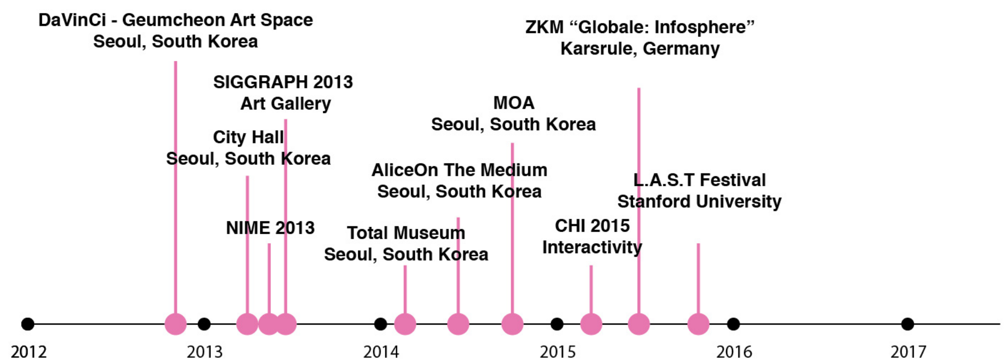

Figure B.0.1: A Timeline of Exhibitions (2012-2016)

Publications

<u>**Han, Yoon Chung**</u> and Byeong-jun Han, “Digiti Sonus v2: New Interface for Fingerprint Data Sonification using Hand Motion” CHI EA '15 Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems, Pages 363-366, April 2015.

<u>**Han, Yoon Chung**</u> and Byeong-jun Han, “Skin Pattern Sonification as a New Timbral Expression,” Leonardo Music Journal Vol. 24, December 2014.

<u>**Han, Yoon Chung**</u> and Byeong-jun Han, “Skin Pattern Sonification Using NMF-based Visual Feature Extraction and Learning-based PMSon”, International Conference for Audio Display (ICAD) 2014, June 2014.

Han, Yoon Chung and Byeong-jun Han, “Digiti Sonus” XYZN: Scale, ACM Leonardo Journal Vol. 46, No.4, July 2013.

Han, Yoon Chung, Byeong-jun Han, and Matthew Wright, “Digiti Sonus: Advanced Interactive Fingerprint Sonification Using Visual Feature Analysis,” Proceedings of New Interfaces for Musical Expression (NIME). 2013. (Full Paper)

Han, Yoon Chung and Byeong-jun Han, “Digiti Sonus: An Interactive Fingerprint Sonification,” ACM Multimedia 2012.

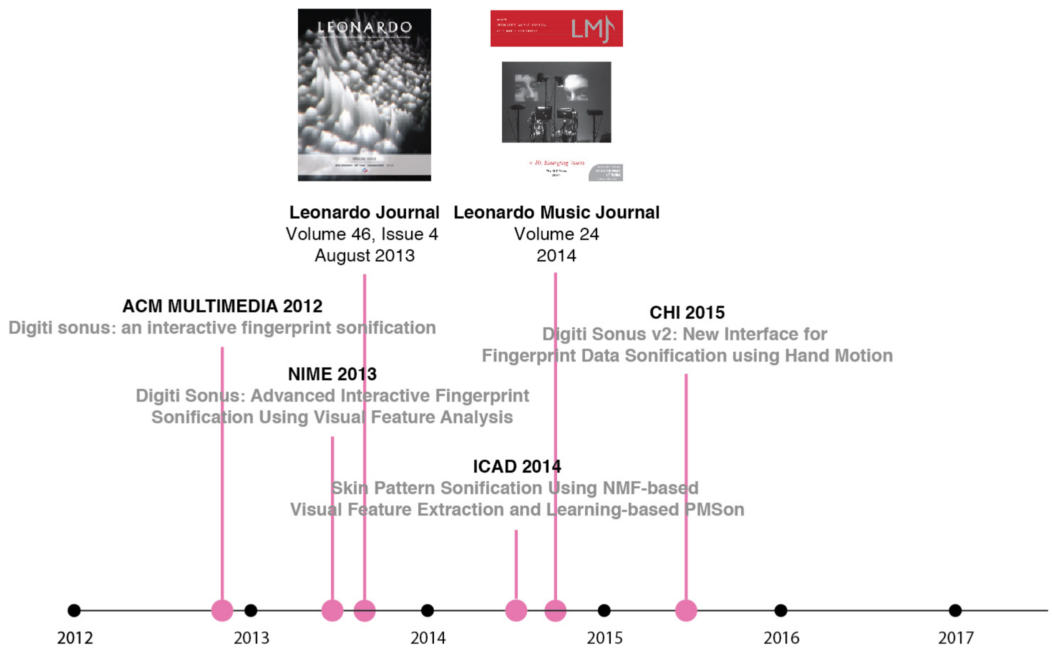

Figure B.0.2: A Timeline of Publications (2012-2015)

Talks and Presentations

- Invited Speaker, Design Seminar, Ulsan National Institute of Science and Technology (UNIST), Ulsan, South Korea

- Invited Speaker, MOOGFEST 2014, Alternative Interfaces organized by Eyeo Festival, Asheville, NC USA www.moogfest.com/speakers/yoon-chung-han
- Invited Speaker, ACM SIGGRAPH Art Talk 2013, Anaheim, USA http://s2013.siggraph.org/attendees/art-talks
- Invited Speaker, ACM SIGGRAPH CG in Asia, Anaheim, USA http://s2013.siggraph.org/attendees/birds-feather/events/cg-asia

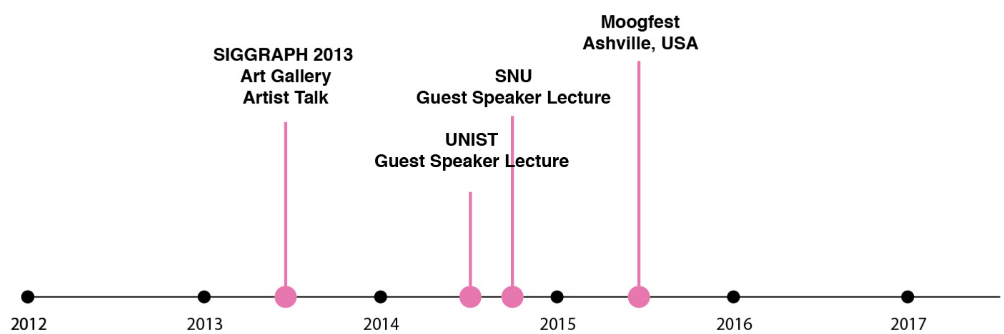

Figure B.0.3: A Timeline of Talks and Presentation (2013-2015)

Awards

- Davinci Media Art Award 2012-2013 at Geumcheon art space, Seoul, South Korea
- AliceOn New Stream 2014, Seoul, South Korea

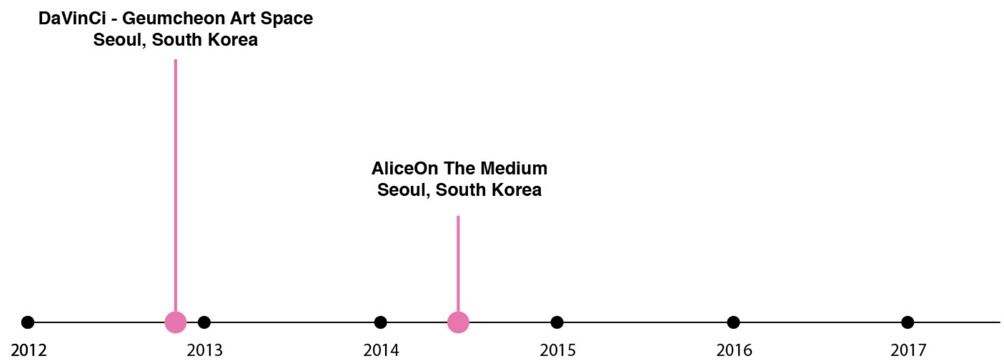

Figure B.0.4: A Timeline of Awards (2012-2014)

C. Reviews from Curators

1. Review from a curator at ZKM, Germany

Yoon Chung Han & Byeong-Jun Han
Digiti Sonus
Infosphäre
ZKM | Zentrum für Kunst und Medientechnologie, Karlsruhe, Germany
05.09.2015 – 31.01.2016

The installation *Digiti Sonus* offers a unique, highly personalized media art experience. Visitors are invited to interact with an interface, which scans fingerprints and transforms them into an open musical score, thus animating a three-dimensional visualization in which the fingerprints take the shape of a vibrant sonification.
Confronted with digital technologies in daily life, we are now all used to projecting ourselves on the device we interact with, and tactility plays a primary role in this process. It is via touch that today's interfaces connect us to the external world, and that we experience our social life.

Inversely, tactility in *Digiti Sonus* is oriented towards the user who sees his or herself mirrored in the visualization. The installation invites visitors to reflect on their own identity, through the subjective and unique sound originating from their fingerprints.
Biometric data are the starting point for engaging the audience in a process of play, placing the visitor in an active position, thus reversing the usual use of biometric data pattern recognition associated with control.

In the installation, interaction enables the visitor to participate and discover an unexpected and unknown side of their identity and personality as well as to have a tangible feeling of their bodily presence in space.

As the work shows, each participant gives shape to a different sound, meaning that musical fingerprints can reflect the complexity and variety of individuals.

The resulting projected image and sound vibrations, can be considered the artistic representation of an ephemeral shape, a sort of hidden otherness which becomes apparent, giving a sonic quality to something that cannot be seen.

In the context of the exhibition “Infosphäre” at the ZKM, Zentrum für Kunst und Medientechnologie, Karlsruhe, the installation *Digiti Sonus* stands as a remarkable example of how a sophisticated technology can become a tool allowing to engage with a diverse and broad audience, ranging from children to adults.

Yoon Chung Han and Byeong-Jun Han’s research unveils the potential of media art. It creates an unexpected and innovative way of accessing and utilizing biometrical data, while creating a musical experience, thus exploring and interrogating the link between interaction and what we can consider active and true participation.

The audiovisual content involves the affective and sensory participation of the viewer. Moreover the installation can create a common ground for others to perceive, listen to the real-time sonic composition. The modulated sonic shape and sound reverberation makes the blackbox a sort of environment which extends the user / interface duality; Digiti Sonus questions the artistic possibilities of media art, and tests the audience’s reaction to the interface, at the same time making the visitor the necessary activator of the work.

Giulia Bini

2. Review from a curator at Geumcheon Art Space, Media City Seoul organizer

Digiti Sonus in the perspective of media art in South Korea
한국 미디어아트의 흐름에서 살펴본 ‘손끝소리’

While the principle, convention and boundaries of art has been collapsed in cultures and countries, it may not be necessary to check her position in the recent history of media art in South Korea. However, her artwork <Digiti Sonus> was created with the support by one of Korean art festivals called DaVinci Idea, and her appearance and the recent flow of media art in South Korea should be investigated.

예술의 원리와 관습 뿐 아니라 문화 간, 나라 간 장벽이 허물어지는 지금, 한윤정이 출생하고 성장한 ‘한국’의 미디어아트 근래 역사에서 그녀의 위치를 확인하는 것이 필요한가. 그러나 작품 <손끝소리>는 ‘다빈치 아이디어 공모’[10]라는 한국 예술제도 안에서 출현한 만큼 한국 미디어아트의 근래 흐름과 그녀의 등장이 제시한 변화를 짚어볼 필요가 있다.

After pioneering media artworks such as Toshio Iwai or Ken Feingold’s artworks have been introduced to South Korea, media art scene in South Korea has not been clearly defined through its fast evolution. However, throughout some notable cases, a system surrounded by the media art in South Korea has been changed from an exhibition-based system to a new system with “creation-presentation-postproduction.” Through one of the most representative case to lead this change, “Davinci Idea,” Yoon Chung Han + Byeong-Jun Han entered to the media art scene in South Korea in 2012.

1998년 한국에 토시오 이와이, 캔 파인골드와 같은 미디어아트의 교과서적 작품이 소개[11]된 이후로 20년 간 한국 미디어아트 씬은 빠른 진화 속에서 명확히 정의되어 있지 않다. 다만 주목할 만한 몇몇 사건들[12]을 통해 한국의 미디어아트를 둘러싼 제도는 전시 중심에

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[10] 서울문화재단 금천예술공장이 2010년부터 현재까지 추진 중인 ‘다빈치 아이디어 공모’는 예술가의 기술기반 아이디어를 매년 10개 선발하여 지원하는 사업으로, 선발된 예술가는 제작비, 전문가 자문, 발표회, 기업후원, 해외진출을 지원받는다. 현재 한국의 신예예술가들이 프로예술가로 데뷔하는 플랫폼으로 성공적으로 자리잡았다.

[11] <사진의 시각적 확장전: 현실과 환상>, 기획: 이원곤, 국립현대미술관, 1997.

[12] 주요 사건을 언급해보면 한국 최초 미디어아트 미술관인 ‘아트센터 나비’의 2000년 개관(한

서 '창작-발표-후지원'에 걸친 시스템 구축으로 변모가 관찰된다. 이러한 제도적 변화를 이끈 '다빈치 아이디어 공모'를 통해 한윤정+한병준은 2012년 한국의 미디어아트신에 사실상 데뷔한다.

Most of media artists in South Korea from 1990s to mid-2000 studied traditional fine art and had amateur technology abilities. However, newer generations such as HYBE, Team VOID and Yoon Chung Han+Byeong-Jun Han show new approaches and boundaries with the previous generation in their creative capability and ways of creation. First of all, they have engineers in their team, which lead higher quality of technological completion. Second, they are free from specific art galleries or art groups. Lastly, they are very active to commercial calls such as automobile, fashion and festivals.

전통적 평면회화를 학습하고 아마추어 기술력을 보유한 90년대 말~2000년대 중반 한국 미디어아트 예술가들[13]을 뒤로 하고 출현한 새로운 예술가들-하이브(HYBE), 팀보이드(Team VOID), 그리고 한윤정+한병준이 보여주는 경향은 창작역량과 활동방식에서 전 세대들과 명확한 선을 긋고 있다.
이들은 첫째, 팀 내부에 공학자를 보유하여 높은 기술적 완성도를 구사하고 둘째, 특정 갤러리 혹은 미술계 계파로부터 자유로우면서 셋째, 자동차회사와 패션브랜드, 페스티벌에 이르는 상업적 호출에 적극적이라는 특징을 지녔다.

On top of their strong engineering technology and favors on commercial business, Yoon Chung Han's works have great interests in making data sensorial recognizable with higher quality of visuals and interactivity to allow the audience to intuitively recognize artworks. (It is not surprised that most of media artists fail to lead the audience to recognize their artworks intuitively)

공학적 기술력의 무장, 비즈니스에 호의적인 공통점 외에 한윤정의 작업은 데이터를 감각적으로 인식시키는 데 대한 관심, 높은 시각적 완성도, 관객에게 작품이 '직관적으로 인식됨으로서' 확보되는 높은 인터랙티비티를 특징으로 한다(놀랍지도 않지만 미디어아티스

국의 통신회사 SK가 설립), 같은 해 시작된 '서울미디어아트비엔날레'(서울시 기획)의 현재까지 존속, 미술대학을 미보유한 대학들의 '미디어학부' 혹은 '영상대학원'의 설립, 2010년부터 7년째 이어온 '다빈치 아이디어 공모 Da Vinci Idea Open Call' 등이 있다.

[13] 이들은 첫째, 회화적 전통이나 전통 조각을 학습하고, 둘째, 스스로 익힌 아마추어 수준의 기술력, 세째, 2차원의 이미지에 시간을 부여하거나 오브제에 동작을 추가하는 방식을 구사해 왔다.

트들은 작품을 관객이 직관적으로 인식하게 하는데 대부분 실패한다.)

As artists in 1960s brought cartoons or commercial advertisement images into their artworks, media artists who are close to science and technology started using biometric data such as brainwave, iris, or vein while bio technology and new media technology are actively combined in 2016. Yoon Chung Han transformed “fingerprint”, the identification information into “artworks” (I guaranteed as a curator of DaVinci Idea!) As “art inspires industry” was the main objective of the “DaVinci Idea,” there is no doubt that <Digiti Sonus> inspired security companies where deal with personal identification information such as VidSys or ADT.

1960년대의 예술가들이 당시 범람하던 만화, 광고이미지를 작품 속에 끌어들였던 것처럼, 생명기술과 첨단기술이 활발하게 결합중인 2016년, 과학 및 기술과 가까운 인척관계에 있는 미디어아티스트들은 뇌파, 홍채, 정맥 등의 생체정보를 작품 속에 끌어들이고 있다. 한윤정은, <손끝소리>를 통해 ‘지문’이라는 개인인식 정보를 ‘작품’으로 전환하였고, (여기서 ‘다빈치 아이디어 공모’의 사업설계자로서 장담하기를!) ‘산업에 영감을 주는 예술’이 ‘다빈치 아이디어 공모’의 목표였던 만큼 <손끝소리>는 VidSys나 ADT 같은 개인인식정보를 다루는 보안회사에게 영감을 불어넣었으리라 믿어 의심치 않는다.

Meanwhile, even though artists who use biometric data including Yoon Chung Han want to talk about the identity of each individual, based on what I have observed the exhibition during one month, most of the audience who experienced the artwork were immersive with a fun part of magnifying unexpected world that would be never realized before. However, with the improvised, and unexpected aspect, <Digiti Sonus> has a great meaning as an artwork, and the audience truly enjoyed the unexpected fact (being out of the Yoon’s intention to draw “investigation on personal identity”) Being that said, Digiti Sonus was very successful among other nine works in DaVinci Idea 2012.

한편으로 한윤정을 포함하여 생체데이터를 다루는 예술가들이 관객 개인의 정체성을 이야기하고 싶더라도, 내가 전시모습을 한달 간 지켜본바, 작품을 경험하는 관객 대부분은 “이 지문이, 내가 모르던 나만의 무엇이었어...”란 깨달음 대신 자신이 몰랐던 우연적인 세계를 따로 끄집어내어 확대해서 보는 재미에 몰입했음을 밝혀야겠다.
그러나 그 즉흥성, 우연성으로서 <손끝소리>는 예술의 자격이 있고, 관객은 (한윤정이 그려놓은 ‘개인 고유 정체성에 대한 탐구’라는 목표에서 맘대로 벗어나) 그 우연적 요소를 즐겼다는 점을 인정한다. 그런 이유로 2012 다빈치 아이디어 공모에서 살아남은 9개의 작품 중에서 유난히 관객에게 사랑받았다.

Manager, Hee Young Kim
GeumCheon Art Space, Seoul Foundation for Arts and Culture
March 2016

김희영 매니저
서울문화재단, 금천예술공장
March 2016

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ix [credit: https://calledtowrite.com/wp-content/uploads/2012/02/fingerprints.png]

x [credit: http://www.handresearch.com/news/dermatoglyphics-multiple-intelligences-test-dmit.htm#music]

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