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Author	シャ, ウゼイ(Xie, Yurui) 稲蔭, 正彦(Inakage, Masahiko)
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Master's Thesis
Academic Year 2023

Movement Quality Visualization for Wheelchair Dance

Keio University
Graduate School of Media Design

Yurui Xie

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

Yurui Xie

Master's Thesis Advisory Committee:

Professor Masa Inakage	(Main Research Supervisor)
Professor Kai Kunze	(Sub Research Supervisor)

Master's Thesis Review Committee:

Professor Masa Inakage	(Chair)
Professor Kai Kunze	(Co-Reviewer)
Project Senior Assistant Professor Atsuro Ueki	(Co-Reviewer)

Abstract of Master's Thesis of Academic Year 2023

Movement Quality Visualization for Wheelchair Dance

Category: Design

Summary

Wheelchair dancing is a notable genre of disability art that is still heavily influenced by ableism and art exclusion. Resources and opportunities that can meet wheelchair dancers' demands are scarce, as well as creating and disseminating performances that are appropriate for their body types and supporting technology. In consequence, this limits their capacity to communicate new ideas and exceeds barriers. Converting existing methodology on the abled dancer and creating effective communication techniques that brings wheelchair dancer into established dance dialogue could be able to aid with these issues. The creation of a visualization system based on Laban Movement Analysis (LMA), which notates movement quality and opens up new perspectives on how people see disabled bodies and the artistic legitimacy of wheelchair dancing, is the aim of this project. Based on LMA basic effort, the system uses video to recognize the dancer's and wheelchair's body landmarks. It then extracts important aspects to provide visualizations of the expressive qualities of time, weight, and space. The present assessment involves a broad public pilot study and an online survey with the following interview aimed at professionals to gather comments in support of real-world deployment and practical implementation. Results from the evaluation demonstrated that visualization can effectively communicate fundamental effort movement attributes and inspire artistic movement creation among professionals and novice dancers. The technique may also be used for performance improvement as well as reflective evaluation, according to the expert consulted through the questionnaire. The LMA visualization tool can be expanded upon and utilized in a number of ways, from performance and documentation to teaching and communication, in order to promote LMA Efforts toward the aesthetic legitimization of wheelchair dance.

Keywords:

disability art, movement recognition, movement qualities, visualization, accessibility, Laban Movement Analysis, human-computer interaction

Keio University Graduate School of Media Design

Yurui Xie

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Chapter 1
Introduction

Dance has stayed in human history since the beginning of civilization, where the earliest traceable evidence can be found in cave paintings. Dance is a complex cultural and art phenomenon that reaches beyond movements and physical ability, and extends towards the layers of emotions and state of mind [1]. The expressive aspect of movement allows the dancer to communicate emotions, intentions, and states of mind to the audience and is an essential element of expressive value. Through movement, using various techniques, a dancer can convey a wide range of emotions, from joy to sadness. For example, a dancer might use light, flowing movements to express calmness, or sharp, sudden movements to express anger or frustration. Movement expression can also alternate one's identity, which leads to the metamorphosis within perceptions and physical bodies [2]. Dancers and researchers use quality of movement to describe the expressive characteristic of dance [1]. However, the nature of dance is time-sensitive, as the artistic expression can change or fade through time in comparison with other traditional art forms [3]. In order to assess artistic expression in dance for training, performance, and creation, the dance industry has adopted various systems of movement analysis and dance notation.

Movement analysis and dance notation can be traced back centuries ago, evidence can be found in the Egyptian hieroglyphs, or the Han dynasty's sculptures [4]. In the eighteenth century, such methodologies gained its institutional popularity among the French court dance and emerging dance forms in other European nations [5]. Nowadays, movement analysis becomes the scientific methodology adopted by established dance styles. Movement can be classified as non-ephemeral, which transcends dance into a permanent "artifact" through the use of movement analysis [6]. Various dance fields have been incorporating movement analysis systems to capture and interpret movement quality for performance [1], style preservation [7], and educational [3] purposes. Among all the movement analysis methodologies, fields ranging from dance to Human-computer interaction(HCI) have adopted the Laban Movement Analysis (LMA) for study and creation related to body movements [8]. Laban Movement Analysis (LMA) provides a framework for analyzing and describing movement in a detailed and systematic way, where it is used to analyze movement patterns, identify areas of improvement, study the relationship between movement and emotional and cognitive states, and design human-computer interfaces that involve movement-based interactions.

To our knowledge, there is little to no resource and implementation of the previously mentioned methodologies for wheelchair dance. Wheelchair dance shares the same obstacles as many other disability arts, which are the misrepresentation, segregation, and hegemony induced by the normality and abnormality of established art [9]. As a consequence, wheelchair dance has suffered from limited visibility and insufficient chances to grow and flourish. Previous research shows implementing LMA in folk dances can benefit minority dance forms by preserving artistic quality through evaluation and education [7]. Access to established dance evaluation practices and a universal dance vocabulary is essential for the development of wheelchair dance and the reconstruction of disability identity. It enables dancers and choreographers to incorporate a wider range of movements and techniques into their performances, provides a common language for communication and collaboration across different genres and styles, and facilitates the promotion of wheelchair dance as a legitimate art form to broader audiences, thereby contributing to the recognition and celebration of diversity and inclusion in the world of dance. It is therefore important that appropriate resources are made available to wheelchair dance in order to promote its growth and recognition in the industry.

The dance industry has incorporated Wearable motion capture devices [10], or depth camera [11], which have been leveraged to simplify movement feature extraction for further investigation. Machine learning tools have also been used for movement quality recognition to enrich contemporary dance artistic capacity [10]. However, previous studies only focused on able-bodied dancers. Most research on wheelchair dance focuses on rehabilitation, education [12], and entertainment aspects [13]. To our knowledge, visualization of movement quality in wheelchair dance has not yet been explored.

In this study, we provide a visualization approach designed exclusively for wheelchair dancing, providing a creative interpretation of movement quality based on the Basic Effort (Figure 2.1) of LMA. The modules of the design framework are concentrated on movement data collection, feature extraction, and visualization. This adaptable architecture makes it a viable option for future Human-Computer Interaction (HCI) applications that aim to raise the aesthetic validity of disability art by allowing for adaptability to a variety of visual expressions and movement-based interactions.

To evaluate our visualization solution, we employed a mixed methodology. Initially, data was gathered during a public interactive exhibition as a pilot study, following an online survey that specifically targeted choreographers and professional wheelchair dancers. Other in-depth interviews with professional wheelchair dancers were conducted with a total of five participants. The outcomes from both approaches demonstrated the effectiveness of our visual approach in conveying expressive information for the exploration of movement and assessment of its quality within the realm of wheelchair dance.

Chapter 2
Background

2.1. Wheelchair Dance and Ableism

The origin of wheelchair dance can be traced back to Europe around the sixties, which first started as a recreational sport known as the para dance. In recent decades, wheelchair dance has grown artistically, where dance companies, such as the Axis Dance Company, have included wheeling dancers to form integrated dance performances [14]. Nevertheless, the aesthetics of dance have long been associated with classical beauty, such as that of an ancient Greek body sculpture [15]. As dance has evolved throughout human history, ballet has emerged as one of the most influential and enduring styles, maintaining a remarkable impact in theater and performance even nowadays. However, Ballet's origin derives from the ancient Greek and Apollonian value of aesthetics, which emphasizes an ideally proportioned body form [15]. This homogeneous perception of dance denies artistic recognition and relevance of wheelchair dance as established art since wheeling dancers often have various portioned body forms than classical ballerinas. Due to the comparatively short history of dance analysis, inclusive practice, and social justice are not widely addressed [16]. Transcending disability into positive artistic appreciation is still hindered by the hegemony ruled by abled-body normality.

The perception of ableism, which perceives the disabled body as inferior to the abled body, subsequently caused the marginalized movement education for disabled body [17], or miscommunication in choreography [16]. Mainstream media, influenced by ableism, frequently presents a limited and one-dimensional representation of people with disabilities, perpetuating a narrow perspective that fails to capture the diverse range of abilities, experiences, and contributions of individuals with disabilities, reinforcing negative stereotypes [18]. Art and art-related industries often pair sorrow, tragedy, mocking, dark, or malevolence with disability. Disability was joked about as human abnormality in freak shows historically [19], portrayed with stereotypical perception in the film industry [18, 19], overly amplifying the tragedy of disability in performance art [18]. This historically rooted ableism restricts society into a binary structure, causing wheelchair dancers to suffer from prejudice in ability and artistic practice [20].

Fortunately, with the impact of social justice movements and the adoption of inclusive practices, numerous scholars, artists, and communities have practiced philosophies and methodologies that challenge the negative connotations associated with disability and promote its positive appreciation [15]. Within the realm of art, disability studies draw upon the interpretation of Edmund Burke's ideas, which question the notion of a rigid correlation between a symmetrical body and conventional beauty [15]. These interpretations argue that beauty is experiential for both the dancer and the spectator and that our interpretation of beauty can be shaped by experiences that help us to *see* differently. The Crip theory, which is heavily influenced by cultural disability studies and originally developed in the United States, also emphasizes the cripping experience that uses disability to deconstruct the binary world under ableism [21]. Crip theory suggests that its process is utilizing a transforming approach to celebrate disability itself, in order to create a positive association with disability [9]. Silvers's study also states that historical and everyday experiences have shaped us into appreciating artwork even if a deviant or "grotesque" art piece is depicted [22]. However, marginalized exposure to disabled bodies leads to a limited perception of deformed bodies and a lack of aesthetic appreciation of real-life deformed bodies [22].

Evidence shows that expanding this artistic appreciation in mainstream dance can be done by introducing various types of bodies in integrated dance [14], or incorporation with folk dance [20]. Despite these initial advances, to our knowledge, there is no study that focuses on integrating wheelchair dance into institutional movement analysis from an artistic perspective.

Therefore, a concentration on disability and the artistic experience in wheelchair dance could potentially cultivate artistic appreciation towards wheelchair dance. On the other hand, integrating with established dance methodology could potentially benefit wheelchair dance and disability art to enhance their artistic relevance and evaluation.

2.2. Effort Description

Harmony and rhythm, as fundamental musical elements, play a crucial role in conveying the embedded message within a piece. Through their interplay, music elicits a wide range of emotions, including melancholy, happiness, and other profound emotional nuances, effectively captivating and resonating with listeners on a deeply emotional level. In a similar fashion, movement in performing art also conveys the emotional and expressive content within a choreography [23]. Artists create sets or patterns in movements to convey their intention and the narration of a certain message. Dancers explore their body movements for performance, as storytellers articulate their words to evoke feelings in their audience. In order to articulate and examine the message of dance, various movement analysis systems were developed. Out of all systems, one of the most renowned and broadly adopted is LMA [24].

Laban Movement Analysis (LMA) is an empirical and scientific method developed by Rudolph Laban in the 1920s, which examines movement, providing a systematic framework to understand and analyze human motion and expression [4]. LMA studies and records dance in a structural standard description (Motif) [25], which uses signs similar to musical scores to record movements systematically. Another system known as the Effort description evaluates expressive quality as the reflection of the dancer's state of mind and the dynamic of movement [4,26,27]. In van Zile's study with Pendleton, the researcher found that when it comes to staging the dynamic of dance instead of a particular routine or movement, the effort description comes to be useful based on its nature of captivating the quality or energy instead of specific movements [3]. LMA's Effort interpretations have also been applied in personality assessment, emotion recognition in gamercise [28], and affective input for interactive applications [29].

The Effort description is rooted in four principle motion factors: Time, Weight, Space, and Flow (Figure 2.1).

- *Time*: Time serves as the embodiment of the pace at which movement unfolds. It is intricately woven into the fabric of motion, influencing its speed,

Motion Factor	Description	Continuum	Example
Time	Embodies the pace of movement	Sustained: Leisurely, slow	Taichi
		Sudden: Fast, haste	Quick Punch
Weight	Embodies the amount of fource excerted	Light: buoyant, force is decreased	Balloon flying
		Strong: powerful, force is increased	Weight Lifting
Space	Embodies the direction of attention	Direct: straight, single attention matching movement intent	Point out direction
		Indirect: deviating, multiple attentions with sinuous movement	Meandering

Figure 2.1: LMA Effort Description.

rhythm, and duration, thereby shaping the expressive qualities and overall dynamic of the physical actions. When movement is indulging in Time, it is *Sustained*, whereas haste is considered as *Sudden* [10]. For example, taking a deep breath during medication is considered as *Sustained*, while a quick punch during boxing embraces the *Sudden* quality. Time Effort encompasses the evaluation of pauses' duration and alterations in tempo as significant factors in the analysis [8].

- *Weight*: Weight embodies the physical manifestation of the amount of force exerted, which encompasses the magnitude and intensity of the force applied, influencing the energy of movement. Weight can be perceived as *light* or *Strong*. Weight is perceived as *Light* when the sensation of force is buoyant and effortless, while a greater magnitude of pressure leads to a sense of *Strong* weight, infusing movement with a robust and impactful quality [27]. A balloon flying away or a ballerina taking a small leap can be notated as *Light* while performing weight lifting is regarded as *Strong*. Laban notator uses the degree of tension to determine the Weight's quality [4].

- *Space*: Space embodies a conduit that bridges movement and attention, which is related to the orientation of the dancer's mind and focus [6]. When the movement and dancer's attention are aligned, Space is *Direct*, while movement and attention have deviated from each other, the quality becomes *Indirect*. Pointing out a direction is *Direct*, and meandering or letting your focus drift away during a dance is *Indirect*. In addition, the relation between focus and the surrounding environment is essential in identifying Space quality. Due to the complexity of notating movements, laban notators also consider the extension of limbs to identify the quality of Space [8].

Only three Effort descriptions are explained in detail excluding Flow, because these three Effort factors make up the Basic Effort system [8]. Flow embodies the mind state of controlling movement [27], where a loosely controlled motion is *free* in Flow, and a moderate motion is *Bound*. However, Flow is not included in the primary focus of LMA's Basic Effort due to its lesser significance compared to Time, Weight, and Space [8]. Flow effort is comparatively indistinct to identify with due to its accumulative characteristics of the pattern of speed, force, and rhythm [4]. Due to its lesser significance compared to Time, Weight, and Space, Flow is not included in the primary focus of LMA's Basic Effort [8].

Motion factors often occur in combination, where multiple qualities are often witnessed in a single routine or movement sequence [4]. Meanwhile, it is also rare to have more than three motion factors in movement [8]. For example, a dancer dropping on the ground and beating the floor can be described as Sudden in Time, and Strong in Weight simultaneously. When the dancers are stretching out with their upper limbs and perform an elongated gradual movement, it can be categorized as Sustain in Time and Strong in Weight. Hence, the identification of Effort should take a collective consideration where the parameter of each Effort factor is taken into account based on the level of significance.

2.3. Recognizing Body and Movement Quality

Traditionally, movement quality was captured through observation by professional notators, limiting access to a select few practitioners [8]. This approach also requires preparation on physical space and time, more important, it asks for professionally trained LMA notators, which is hard to access for individual artists or small dance companies.

Technological advancements in motion capture, including optical-active, optical-passive, marker-based, markerless, and inertial measurement unit (IMU)-based technologies, enhance accessibility by automating the capture of movement quality. In a marker-based approach, high-quality motion capture data from mocap-suit can reconstruct skeletal structure to recognize style quality in folk dancing [7], and generate real-time movement tracking to aid research participants for movement quality [30]. However, mocap-suit can have difficulties in depicting near floor movements [30], the setup procedure requires additional help and is not cost-efficient, which would impose greater difficulties for users with disability. The optical-active motion tracking is an alternative to offer high-quality motion data with trivial limitations on movements, but the post-processing time and sensitivity of surroundings are the drawbacks of such an approach [31, 32]. The utilization of IMU-based tracking methods provides readily accessible and convenient options for achieving performance or exhibition purposes, which the

EMVIZ has utilized the real-time motion tracking system EffortDetect to visualize movement quality [10]. However, the IMU-based method could only offer limited motion data, and to construct a skeleton structure, the IMU-based method has to sacrifice light sensor implementation. On the other hand, Kinect-facilitated motion capture grew to be popular and has also been used for processing movement qualities for holistic data capture and real-time processing [11,33–36]. While the Kinect excels in capturing extensive movements, offering accuracy and cost efficiency, it may encounter challenges when capturing subtle movements or when there is interference from other objects [30, 34, 36]. Hybrid implementation combining IMU and vision-based sensors introduced flexible movement tracking but still requires sufficient knowledge, financial ability, and physical space for setting up [8, 37]. Therefore, we look at what motion capture method can offer relatively holistic data capture which can also extract skeleton structure with a cost-efficient budget and ease of access.

Recently, researchers have developed a virtual Kinect that resembles the physical Kinect V2's ability but is fully digital with granted access [38]. This system processes video-based input through Google's Mediapipe open source for movement tracking where it offers similar joint data and RGB data as Kinect, which eliminated the requirement of motion tracking hardware [38]. Another important aspect to consider is that this research commenced during the COVID lockdown period, making it exceedingly difficult for participants and researchers to access motion-tracking hardware. This serves as a significant constraint that must be taken into account. Hence, a simple video-based (smartphone or webcam) pose estimation could allow an unconstrained and user-friendly motion capture for wheelchair dancers.

On the other hand, current data sets and tracking methods in overall motion capture lack the embodiment of diverse body forms. No data sets were found for people with disabilities in sports, artistic expressions, or everyday tasks, beyond medical questions like diagnosis or rehabilitation monitoring. Although reviews suggest that motion capture can help disability-related activities, standardized movement tracking for disabled bodies is still insufficiently investigated [12, 39]. Over the past few decades, there has been a notable surge in research dedicated to movement tracking and movement data classification in disability sports. These investigations have paved the way for advancements in adaptive sports technology and have fostered the development of more inclusive training strategies, sports classification, injury avoidance, and performance enhancement for athletes with disabilities [39]. However, individuals with a disability rarely share the exact mobility, or body forms, which poses challenges to most technological implementation. Therefore, there is no standardized movement-tracking application for disabled bodies, the implementation has to consider from a case-to-case perspective to satisfy the targeted user. In disability sports, movement tracking utilized a stereophotogrammetric system, video analysis, wearable technology, and hybrid application to capture movements from athlete [39]. The application of such technology has to take assistive technology into consideration, especially for wheelchair users.

There are few investigations on capturing wheelchair movement in Human-Computer Interaction (HCI), such as using wheel rotation speed as input for dance games, which created an entertaining experience of riding a wheelchair to alternate the stereotypes associated with wheelchair and disability [13]. Specified kinematic data sets are acquired through IMU-based motion tracking to improve athletic performance for wheelchair basketball athletes that can potentially benefit wheelchair-associated activity through developing suitable training procedures and wheelchair design [40]. A marker-based approach that captures the elbow, and wrist on the sagittal plan to study the propulsion of wheelchair maneuvering also offered a new approach to capturing both user's and wheelchair's movements [41]. A cost-effective and adaptable implementation of a wearable motion tracking approach combines marker-based and EMG sensors to capture both the motion and muscle response of wheelchair users [42]. However, the mentioned motion tracking methods are case-specific [13, 40], which offer inadequate motion data for LMA movement quality processing. The wearable approach can also impede overall mobility and movement flexibility when it comes to dance movements [41,42]. On the other hand, motion tracking that separates wheelchair user and wheelchair can potentially impose an implicit idea as a wheelchair as solely an assistive tool that indicates its user's inability or abnormality. Previous studies have revealed that wheelchair dancers perceive their wheelchairs as an extension of their own bodies, fostering a profound sense of embodiment and artistic expression [43].

Movement tracking Integrated with LMA							
Motion Tracking Method	Category	Abled Body	Disabled Body	Data Captured	Advantage	Disadvantage	*Citation*
Motion Capture Suit	Markerbased	☑	☐	Time: movement velocity & movement acceleration Weight: deceleration of motion Space: head orientation	High quality motion capture data; recovable the skeletal structure from captured data	Delayed motion data processing	*[7]*
Rokoko motion capture smartsuit	Markerbased	☑	☐	positional data	available in real-time	difficulty in depict translational movements along the floor ,various morphology creats obstacles in recognizing periphery	*[30]*
Kinect	Markerless	☑	☐	RGB and depth stream data; using x, y, z of 21 joints to construct right wrist skeleton data; secondary data processed into velocity / acceleration; positional data of 12 selected joints (6 left joints & 6 right joints)	Percision on large movements; device is cheap and acessable; Data can be categorized into body, space and shape; offer both RGB and depth data; higher accuracy; affordability; non-intrusive; detailed information	Decreased percision on subtle or small movement; Kinect filters information after 6HZ, which caused losing of important movement information; requires preset-up and distance calibrition	*[33] [34] [35] [36]*
PhaseSpace Impulse X2	Optical Active	☑	☐	motion clips	accurate and holistic motion capture	preset-up, space, sensitive to surroudnings	*[10]*
Optical motion capture system	Optical Active	☑	☐	positional , trajectory data	No limitation on movements; convienient application; high sampling rate	postprocessing is time consuming; poor performance for real-time implementation; sensitive to light and surrounding	*[28]*
mocap, inertial sensor, EMG	hybrid	☑	☐	positional data, dynamic data, physiological data	holistic and conprehensive data capture, adaptable for model training	requires guided set up or professional knowledge	*[32]*
mediapipe	webcam/video input	☑	☐	joints data & RGB	no hardware requirement	the z dimension data is estimated instead of accurate capture with video input	*[8]*

Figure 2.2: Movement Tracking Integrated with LMA

Movement Tracking for Wheelchair Users							
Inertial Mearsurement Units	IMU based	☐	☑	1) average of the best five rotational speeds in a turn (1.5 to 1.5 m/s forward speed); 2) average rotational acceleration; 3) average forward acceleration in the first 2 m from standstill; 4)average forward speed; 5) average rotational speed in a curve (4 1.5 m/s forward speed); 6) average of five best forward speeds	obtain specific movement data	lack of standartized protocols and hardly adaptive to the heterogeneous traits of disbility	*[38]*
Gyro sensor	IMU based	☐	☑	rotation speed of each wheel	easy access, less requrirement on calibration, dose not interfere with the wheelchair user's body movement	marginalized singular data can not depict the entire movement (especially for dance movements)	*[40]*
IMOCAP-GIS	IMU based	☐	☑	vector data of ultrasonic sensor; Euler angle of intertial motion sensor, temperature, optical encoder	able to operate in wirless network, offline data transmission, conducted for rehbiliitation previously	captures only upper limb movements	*[13]*
ArUco & Open CV; camera; EMG instrument	Markerless	☐	☑	trajectory data from upper limbs; rotation of larger wheel;	less requirement on hardware configuration; easy to customize; able to track wheel rotation;	marker can be hard to detect due to certain movements and positioning inrelation with the recording device;	*[37]*
ArUco & Open CV; camera; EMG instrument	Hybrid	☐	☑	positional data, RGB data, muscle dynamic data	adaptive to any wheelchair; low manufacturing cost; capture both motion and electromyography in real conditions	not feasible to measure two signals simultaneously within a single time unit; prolonged processing time; error rate depends on the velocity of marker	*[41]*

Figure 2.3: Movement Tracking Integrated with Wheelchair

These studies have uncovered a deep sense of embodiment and artistic expression among wheelchair dancers, emphasizing the profound connection they feel with their wheelchairs. This perception allows them to seamlessly merge their movements with the wheelchair, resulting in a unique and captivating form of artistic expression that transcends physical limitations. Hence, we contend that when utilizing motion tracking technology for wheelchair dancers, it is crucial to carefully consider the interdependent relationship between the wheelchair and the dancer.

Research identifying movement quality is also limited to conventional body form in data classification. Movement classification using Hidden Markov Models [8], Isomap classification [7], and rendering effects [11] either focuses on the entire *abled* bodies or relies on segmented body motion with sufficient motion data. There are still gaps between motion capture implementation, motion data calibration, and disabled bodies, such as wheelchair users, which should be addressed before the recognition of movement quality and further application of artistic interpretation.

2.4. Movement Quality Visualization

Contemporary choreographers frequently encourage dancers to produce movement in response to directions that require them to build mental images [44]. The mental image is an imaginative perception of a certain object or scene that is not presented in the real world but is portrayed in an individual's mind space. The most common activity that involves the creation of mental images is daydreaming, and the formation of mental images is crucial in artistic expression and creativity. Within a dancer's mind, mental images evolve around sensory modes, encompassing the realms of music, touch, and the visceral sensation of movement, merging to shape a vivid and multi-sensory landscape of artistic expression. Visual art disciplines have leveraged the expressive perception of dance as inspirations, from Pablo Picasso's Les Demoiselles d'Avingon [45], Henri Gaudier-Brzeska's Red Stone [45], Edgar Degas's Ballet Rehearsal [46], to the Total Theater of Bauhaus [47]. Additionally, visualization of mental and emotional expressions also serves as an alternation or unification of forms and identity. In Oscar Schlemmer's Vordruck, female body identity is transferred into the male body through visual design [48]. The Bauhaus total theater unites space and body as an organism through stage design [49]. These examples show how visualization can bridge information across different artistic languages and identities.

Centered in the concept of choreutics [1, 50], also known as egocentric [51], structural visualization from LMA is able to demonstrate movement and state of mind in unity. Laban's book of choreutics, outlines the invisible scaffolding of the body, kinesphere, to understand the mental aspect of movement [50]. Oskar Schlemmer's study of body motion in relation to form suggests spatial-temporal representation as an extent of dance and inner mind [51, 52]. Previous research also illustrates how visual metaphors [10], color synthesis [53], and 3D environments [44] can be used to depict neurological and emotional aspects of the movement. Through visualization, Dance, a non-verbal communication, is able to be poetically studied [45] and functionally analyzed [52]. Meanwhile, the convergence of movement and mind enables their simultaneous embodiment within a universal expression. Through this synergy, physical actions and mental states intertwine harmoniously, creating a unified whole that reflects the interconnections of body and consciousness.

Chapter 3
Design Solution

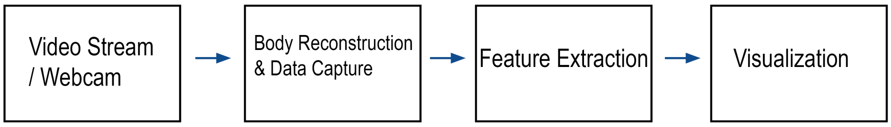

Figure 3.1: Design Solution Flow Chart.

The objective of this research is to create a specialized movement quality visualization tool that is tailored exclusively to accommodate the requirements and creative aspirations of wheelchair-using dancers. This tool aims to enhance their artistic expression by providing visual representations and feedback on their movement techniques, enabling them to explore and refine their performances with greater precision and artistry.

During dance practice, dancers employ the cognitive mapping process to encode spatial information, which aids in enhancing movement recall and cultivating a heightened sense of spatial awareness [54]. This process involves integrating sensory cues and feedback, enabling dancers to create internal representations of dance sequences and navigate their movements with greater precision and spatial understanding. A wheelchair dancer's mental imagery encompasses not only their body but also incorporates the presence and movements of their performance wheelchair. By harnessing the power of cognitive mapping, wheelchair dancers can refine their choreography, strengthen their relation with assistive tools, and deliver performances that reflects the inner embodiment of dance, art, disability and assistive tools.

According to Laban's Choreutics, while there is one central kinesphere of a body, each body part can have its own kinesphere based on its position [50]. To understand Choreutics and kinesphere, one has to trace back on Laban's previous architectual training and the architectural perception of "Body Architecture" [55]. Human body has its own structure and the motion along with each body parts trace an invisible grids around our core, which is how the kinesphere is created. Each body parts encompass a comprehensive array of movements as how each planet composites our solar system, which delivers a universal movement patterns. Meanwhile, every individual body parts move around the correspondent joints, muscle groups as how each planet or comets orbit on their own path. Therefore, in our approach, we consider the dancer's body and wheelchair as an integrated entity, forming a unified kinesphere shared by both and possessing their own kinesphere simultaneously [14].

This design solution is presented through three modules (Figure 3.1): body reconstruction for data capture, movement feature extraction, and Effort visualization. The following sections describe each module.

3.1. Body Reconstruction for Data Capture

To fully integrate the notion of the wheelchair as a bodily extension, we employed Laban's theory of kinesphere and choreutics, reconstructing the body's perception through the utilization of carefully designed body grids (Figure 3.3). The reconstruction introduced the idea of deconstruction to reconstruction [56] from an architectural perspective to provide wheelchair's own kinesphere and integrate dancer and wheelchair as an unified entity with one common kinesphere. This method enables the selection and calculation of body landmarks (Figure 3.2) acquired from the MediaPipe pose (Figure 3.2) library[1], a machine-learning solution for live streaming media.

The three key elements of body reconstruction are:

3.1.1 Frontal Plan

Laban's kinesphere contains wide sanctums of geometrical structures which ranging from two dimensional grid plans to three dimensional geometries. One of a

1 Available at: https://google.github.io/mediapipe/solutions/pose.html

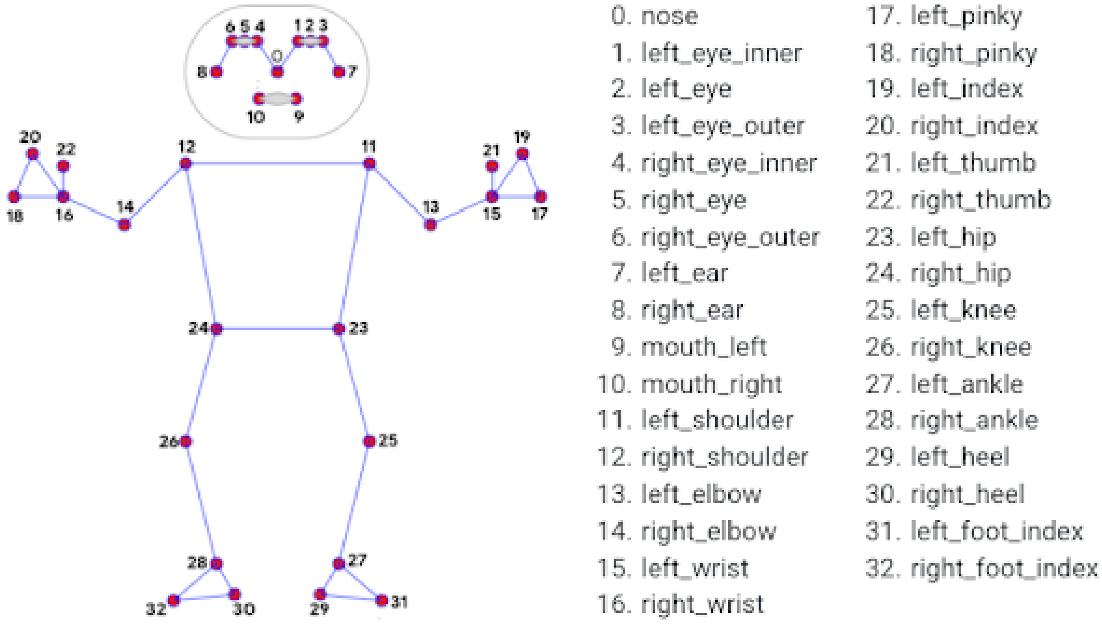

Figure 3.2: MediaPipe Pose Landmarks

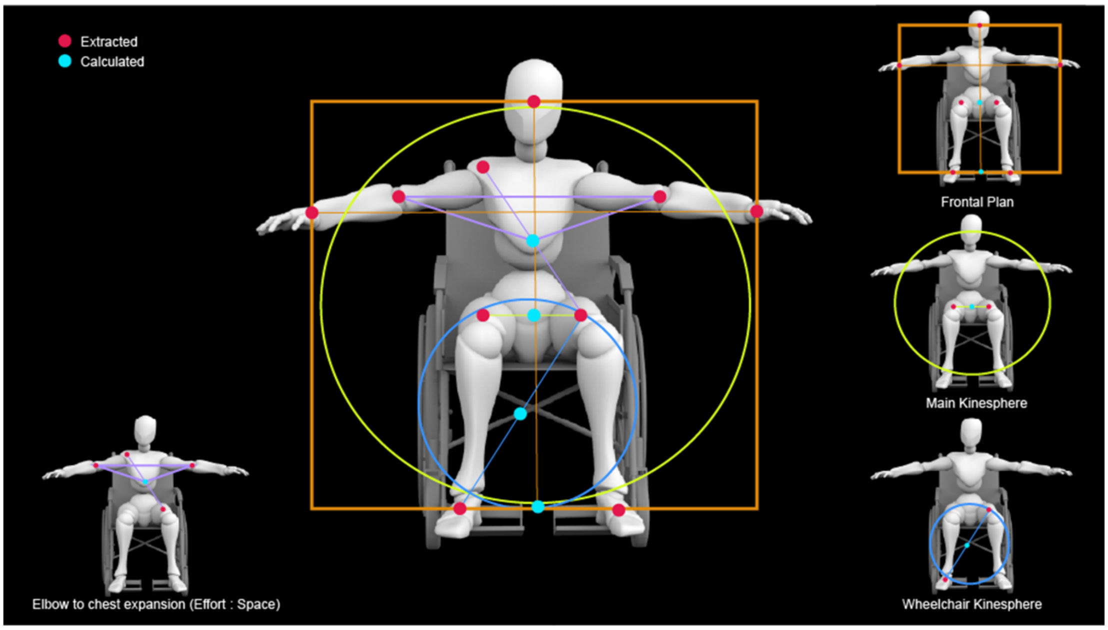

Figure 3.3: Grid System for Body Reconstruction

commonly known kinesphere resembles the Cartesian coordination system with plans correspodning to the x, y, and z direction [54]. The frontal planar was also introduced not only in LMA but also in visual art or architecture, such as Albrecht Dürer's painitng or the body girds from Le Corbusier [54]. The frontal plan are often constructed as a bounding plan around the body's periphery representing both vertical and lateral dimension, which often serve as a basic reference to construct more complex kinesphere or body grids. In our approach, the frontal plane serves as an abstract coordination plan derived from the body's extension. In order to establish this, we identify essential anatomical landmarks such as the left wrist, right wrist, nose, left ankle, and right ankle. Through the computation of the midpoint between the left and right ankle, we derive a comprehensive representation of the body's periphery, capturing the entirety of its spatial boundaries and structural alignment. This method allows for a detailed and inclusive understanding of the body's positional dynamics and spatial relationships.

3.1.2 Main Kinesphere

The LMA choreutics concept takes theory from egocentirc point of view, which can be traced back to the "body-cross axes" [25]. In the concept of egocentric perception, the center is perceived as an intrinsic part of the referenced system, indicating that the body's center becomes the focal point around which the intersecting axes of each individual's body revolve. This framework emphasizes the significance of body center orientation within one's own bodily reference frame. Hence, the design solution recognizes that the primary kinesphere originates from the central point of the body, more precisely the midpoint between the hips. This decision is informed by the consideration of the specific seated position assumed during the performance of wheelchair-related activities, taking into account factors such as stability, comfort, and ergonomic alignment. As a result, the wheelchair aligns with the primary kinesphere of other body parts, promoting a harmonious spatial relationship among them.integration.

3.1.3 Wheelchair Kinesphere

Since wheelchair also makes up the new unified entity with the dancer, wheelchair's kinesphere needs to be extracted.To determine the kinesphere of the wheelchair, we derive its estimation by considering the midpoint along the diagonal line that connects the right hip to the left ankle. By utilizing this specific reference point, we calculate and define the spatial boundaries within which the wheelchair can move comfortably and effectively. By employing this approach, we can ascertain the the wheelchair's mobility and spatial occupation, guaranteeing its seamless integration within the broader kinesphere of the dancer's body. This methodology ensures a harmonious coexistence between the wheelchair and the dancer's movements.

Before implementing motion data capture, adopting a unified organism perspective in the reconstruction of the body and wheelchair brings forth a fresh outlook. This approach enables us to extract ten essential body landmarks from the extensive set of 33 landmarks generated by MediaPipe (Figure 3.2). Moreover, we compute three additional body landmarks: the center of the primary kinesphere, the kinesphere specific to the wheelchair, and the central point of the chest. These calculated landmarks greatly contribute to accurately identifying the body's formation during feature extraction.

3.2. Feature Extraction

The traditional way of identifying and recording Effort from dance depends on the LMA expert or notators. The LMA experts has to be present during the dance or watching the recorded footage to evaluate the movements and classify them into appropriate Effort quality. Needless to say such approach is time-consuming and skill-intensive, which would not be applicable in variety of wheelchair dance performance or practice. Therefore, the feature extraction stage alternate technology into the LMA expert to classify movements into correspondent Effort quality. The feature extraction heavily relies on the comprehensive description of selected motion factors. Within human movements, it is important to note that Effort parameters not only coexist simultaneously but also interact and influence each other [10]. LMA describes the Basic Effort with only Time, Space, and Weight, excluding Flow [8]. The design of feature extraction is based on the definition of

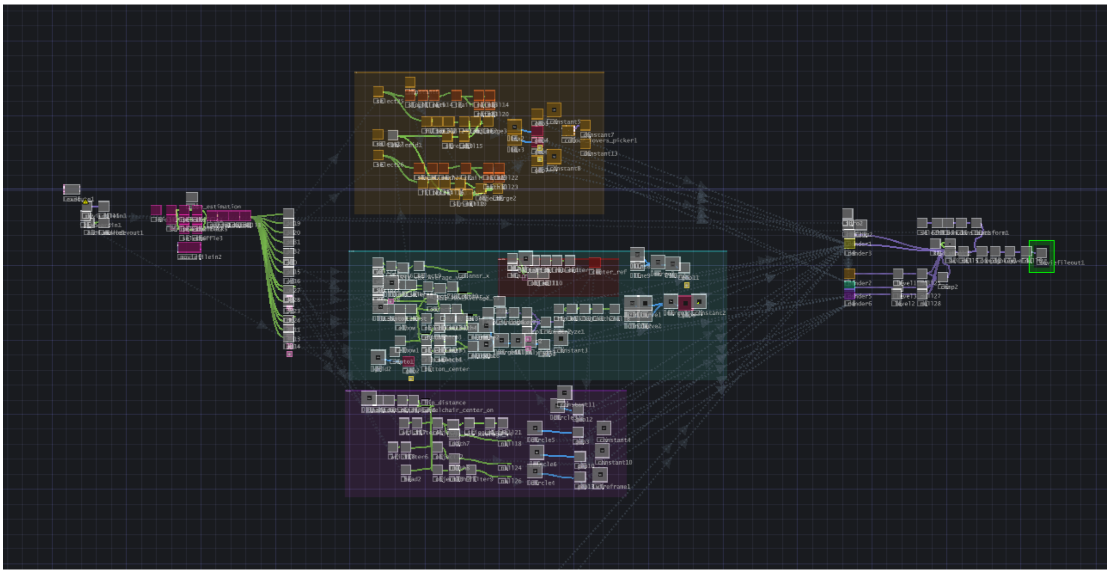

Figure 3.4: Touchdesigner Build Environment

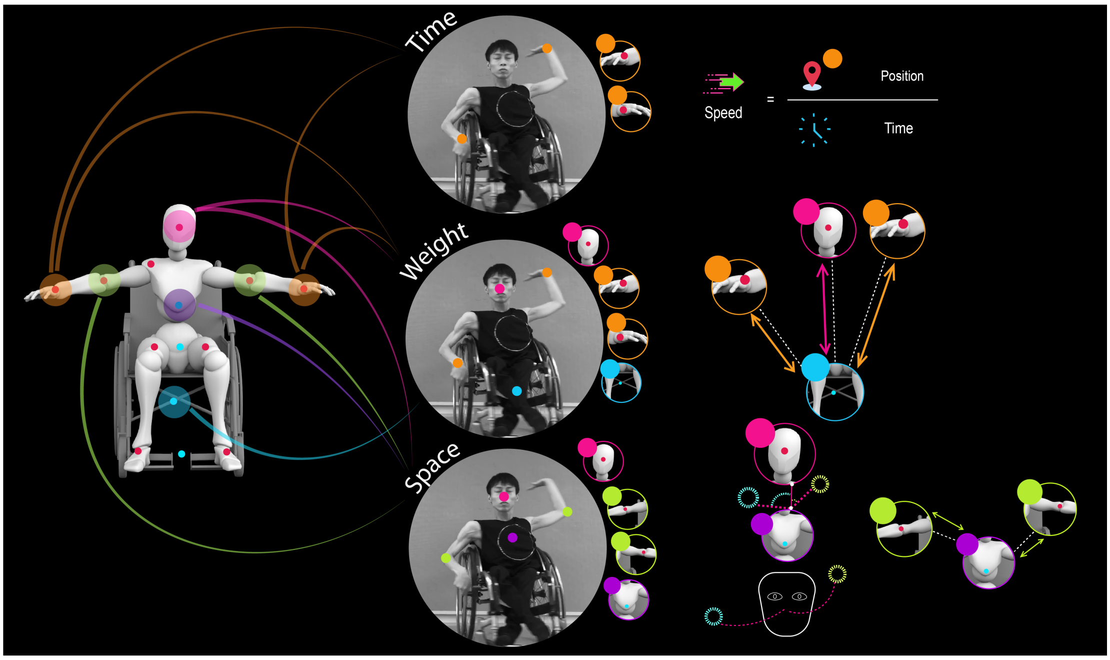

Figure 3.5: Movement Feature Extraction. Choreography © Kenta Kambara

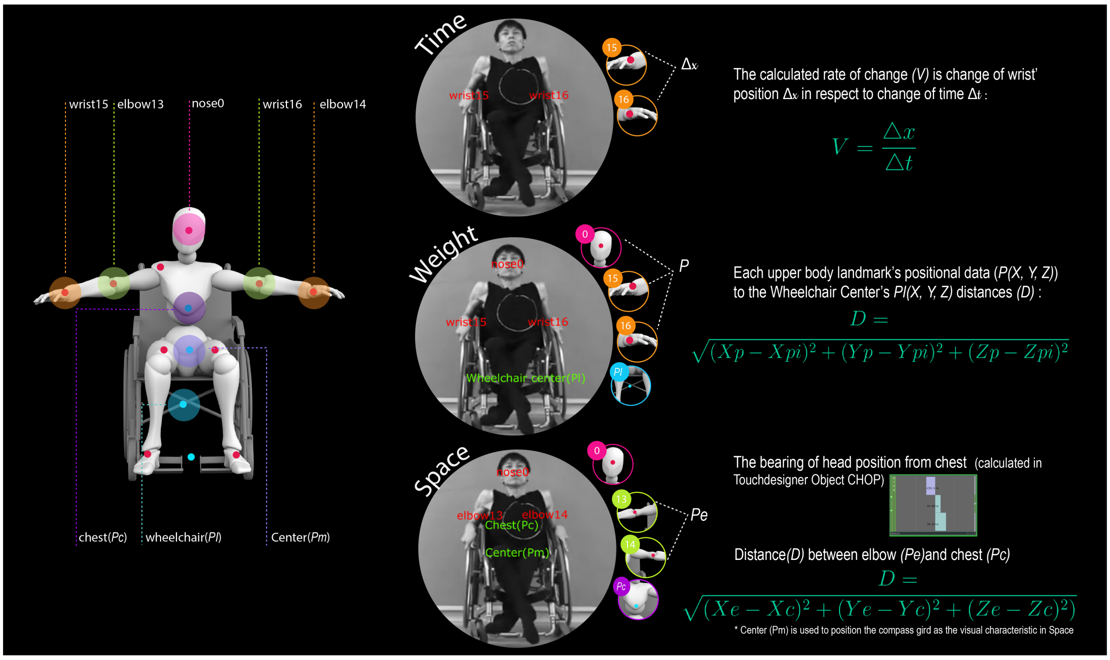

Figure 3.6: Movement Feature Extraction Equation. Choreography © Kenta Kambara

each Basic Effort, respectively Time, Space, and Weight categories, as shown in Figure4 3.5. By analyzing and extracting features related to Effort in the Touchdesigner environment (Figure 3.4), we gain valuable insights into the nuanced characteristics of movement, enabling a more detailed and nuanced representation of the observed motions (3.5). This approach enhances our understanding of the intricate dynamics and expressive elements inherent in the captured movements.

3.2.1 Time

Time represents the rate of change in movement (Figure 2.1, which we often perceive it as speed. Through the analysis of videos, it is evident that wheelchair dancers frequently utilize their upper limbs to perform expressive movements, resulting in a heightened perception of speed in the upper body extremities. This emphasis on the upper limbs facilitates a more pronounced and observable display of velocity during their performances. Time is thus implemented using the rate of change of each wrist positional data (Figure 3.6) according to the concern of visibility during movements and the embodiment of the collective movements. Positional data from each wrist is calculated with the first derivative as the representation of Time, providing a dynamic measurement of movement progression and trajectory.

3.2.2 Weight

In Effort Weight is described as the amount of force or pressure embodied in the movements (Figure 2.1). Gravity frequently influences the Weight within our physical bodies. The classification of Weight takes into account these dynamics by assigning reduced force during body extension, resulting in a perception of lightness. Conversely, Weight becomes more prominent when the body contracts, conveying a sense of strength. This classification captures the nuanced relationship between body movements and the varying perception of Weight.

When considering wheelchair dance, the center of the wheelchair serves as the reference point for determining the level of body extension. Since lower body motion is constrained when dancers are seated in wheelchairs, the positional data from the nose, left wrist, and right wrist are chosen to represent the movements of the upper body (Figure 3.5). By focusing on these key points, we can capture and analyze the expressive gestures and dynamics of the upper body in wheelchair dance performances. The distances between the positional points of the upper body and the wheelchair center play a crucial role in determining the nature of a movement as either Light or Strong (Figure 3.6). This classification depends on whether the distance increases or decreases. Specifically, an increase in distance signifies a Light movement, while a decrease signifies a Strong movement. By analyzing and interpreting these changes in distances, we can discern the qualitative characteristics and dynamic qualities of the upper body movements in wheelchair dance.

3.2.3 Space

Space is determined by the alignment of focus directly to the movement (Figure 2.1). Additionally, Laban experts use the extension between elbow to chest as a generic indication of the Space quality as mentioned in section 2.2. Although outliers and exceptions can happen due to the complexity of dance, such assumption can help to simplify the identification process for the LMA experts. To represent the intended focal direction and movements for this design, a grid compass was developed using two key factors: the orientation of the head on the Frontal Plane and the extension between the elbows and chest (Figure 3.5). The direction is represented by the bearing of the nose landmark from the calculated chest center, which describes a dancer's face direction(Figure 3.6). Therefore, this represents the focus direction in a spatial-temporal relation, which can be further compared with wrists' movement to identify *Indirect* or *Direct* quality. To facilitate the degree of elbow to chest extension, the distance between the chest and each elbow is computed for future reference and analysis(Figure 3.6). This measurement contributes to understanding and visually representing the level of extension achieved in the upper body movements for Space quality identification.

3.3. Effort Visualization

LMA is frequently regarded as the "musical score" for dance movements due to its significant emphasis on visually indexing the contents of movement, such as

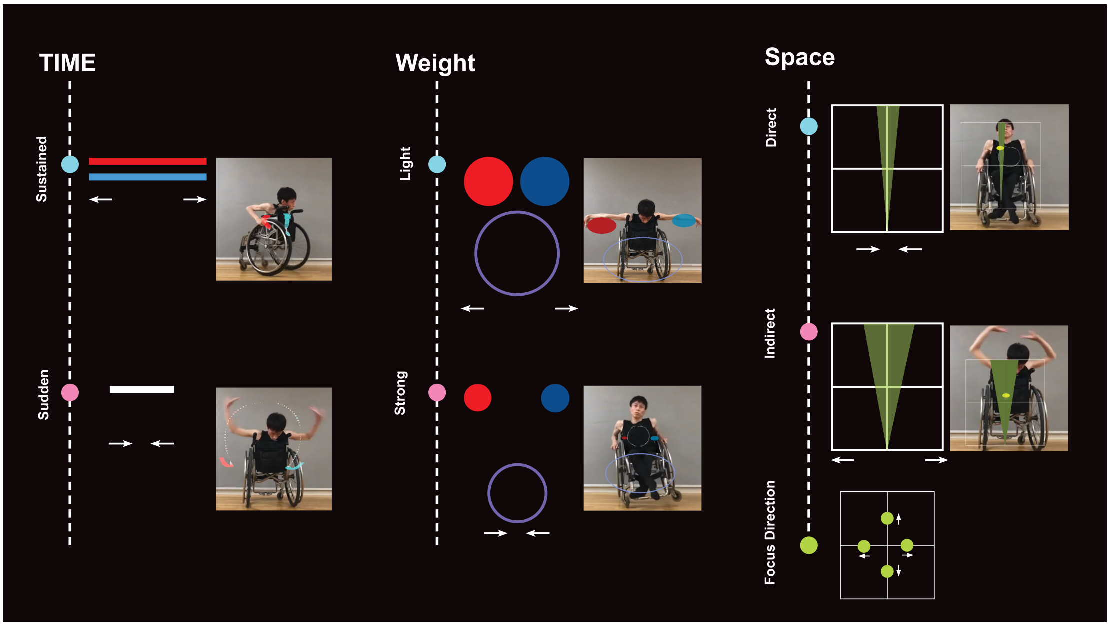

Figure 3.7: Visual Translation of *Basic Effort*. Choreography © Kenta Kambara

its motif system [4]. Through its visual indexation of movement contents, LMA facilitates a deeper exploration and interpretation of dance, enhancing the expressive potential and communication of dance practitioners. The visual representation conveys messages to foster communication with dancers and can also archive dance movements, which can alternate dance as an ephemeral art into an artifact. However, the Effort quality is often visually represented through the effort grid chart that diminished the presence of body form or movement dynamic [25]. This visual representation requires the user to engage in certain learning progress to be able to fluently navigate in the system. Therefore a new and efficient visualization that demonstrating the Effort quality is significant to the deploy of this design solution. Initially, in order to communicate efficiently and eliminate potential confusion, color is employed as a means to facilitate the identification of different body segments in a straightforward manner. Within our design, the utilization of blue and red hues serves to symbolize and distinguish the left and right sides of the body, respectively. The extracted movement features are visualized utilizing affordance properties of line, color, and shape to convey perceptual information of movement quality, see Figure 3.7.

3.3.1 Time

The perceptual sense of time can be conveyed through the length of a line, wherein longer lines often evoke a perception of greater duration or passage of time, while shorter lines imply a shorter duration [10]. This relationship between line length and temporal perception plays a crucial role in visual representation and understanding of time-based phenomena. In our approach, the visualization harnesses this feature to visually narrate the Effort quality of Time. A shorter line signifies a rapid movement, implying a sense of quickness or abruptness that fit into Sudden quality. On the contrary, an increase in line length indicates a Sustained movement quality, suggesting continuity or prolonged action (Figure 3.7). Moreover, color is integrated to accentuate the temporal aspect. Specifically, when the movement quality is categorized as Sudden, the lines are accompanied by a white highlight, drawing attention to the temporal dimension. The visualization of wrist movement is presented within a continuous duration of two seconds, enabling the depiction of ongoing motion rather than a static pose.

3.3.2 Weight

To visualize the concept of weight, we employ three circles positioned in alignment with the dancer's nose, left wrist, and right wrist. The scale of these circles serve as visual representations that depict the distribution and perception of weight in relation to the dancer's movements. The scaling of the circles corresponds to the degree of body extension, effectively visualizing the quality of Weight. As the scale increases, it signifies a greater extension and accentuates the quality of light. Conversely, a decrease in scale mimics the movement of body contraction, indicating the quality of Strong and emphasizing a sense of strength and compactness in the visualization. Each circle corresponded to the left and the right wrists represents the upper limb force generation. The circle centered at the wheelchair indicates the release or contraction of the overall body, which is also known as the body's core.

3.3.3 Space

To represent direction and to depict direction of focus and movements, the visualization of Space resembles a compass (figure 3.7) featuring the directional dot on the Frontal Plan centered at the main kinesphere (Figure 3.3). This compass visualization is juxtaposed with the trajectory of the wrists. When the movement aligns with the focus, the trajectory direction of the wrists converges or moves towards the designated focal point. This alignment between the movement and the direction of the wrists' trajectory emphasizes a cohesive connection and reinforces the intended focus direction.The scaling of the triangle on the grid serves as an additional descriptor of the Space quality, as it visually represents the change in elbow-to-chest distance through scale variations. To avoid any confusion, the Space qualities are visualized using a light green color, providing a clear and distinct visual differentiation.

Collectively, the visual representation formed by these elements resembles a notation system akin to a musical score or Laban Movement Analysis (LMA) motif. This notation enables readers to assess and evaluate the quality of wheelchair dance while also serving as an inspiration for further movement exploration. It provides a tangible and accessible means to interpret and analyze the nuances of wheelchair dance, fostering creativity and deeper understanding within the realm of movement expression.

Chapter 4
Evaluation

The evaluation of our movement quality visualization underwent a two-stage process. The initial stage entailed the implementation of a pilot study conducted within the context of a public exhibition. This was subsequently followed by the administration of a targeted online questionnaire tailored specifically for professional artists. The second stage encompassed a series of in-depth interviews conducted with professional wheelchair artists, aiming to conduct a comprehensive evaluation of the visualization system.

4.0.1 Pilot Study

In November 2022, as part of the KMD Forum exhibition, we presented an interactive visualization and actively engaged with a diverse audience consisting of twenty-five participants who were recruited from the general public (Figure 4.2). This public exhibition provided us with a valuable platform to showcase our visualization and obtain feedback from individuals representing various backgrounds and perspectives. By involving a diverse range of participants, we aimed to gather a comprehensive understanding of their impressions, experiences, and insights, thereby enhancing the validity and reliability of our evaluation process.

Evaluation Setup

The participants were given specific instructions (Figure 4.1) to assume a seated position in a wheelchair and engage in guided movements related to the concept of *Time*. These movements included reaching upward at varying speeds. Throughout the activity, the participants' movements were captured in real-time using a webcam, allowing for accurate and immediate visualization of their actions (Figure 4.1). To provide real-time movement quality feedback, a screen displaying the generated visualization was positioned in front of the participant.

In addition, participants were presented with both video and image formats of the generated visualization depicting Kenta Kambara's Sun Dance, a performance by a professional wheelchair dancer, specifically related to the concept of *Time* (Figure 4.2). Subsequently, they were asked to identify the Effort quality demonstrated in the visualization through a series of multiple-choice questions(Figure 4.2). This activity aimed to gauge participants' ability to discern and interpret different aspects of movement quality within the context of the visualization, thereby providing valuable insights into their perception and understanding of Effort characteristics.

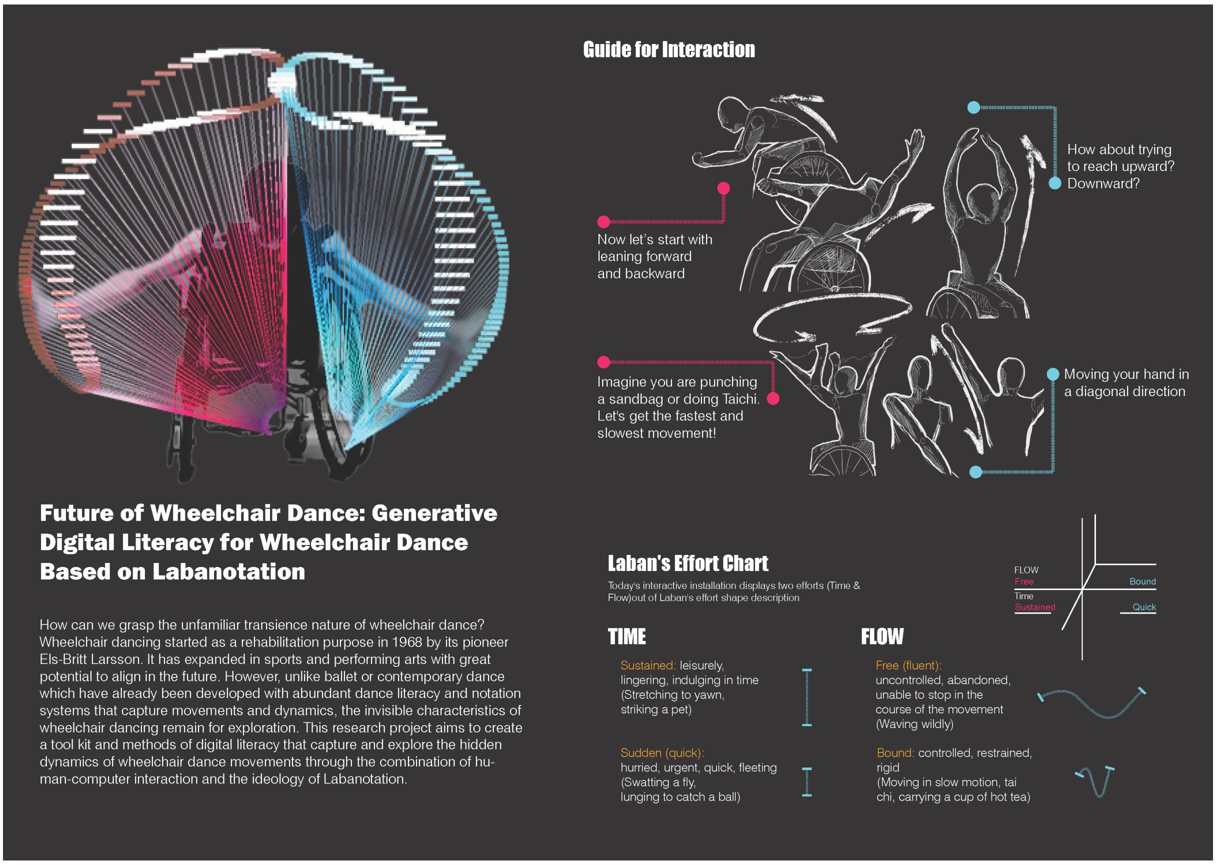

Figure 4.1: Instruction of Movement Poster for KMD Forum

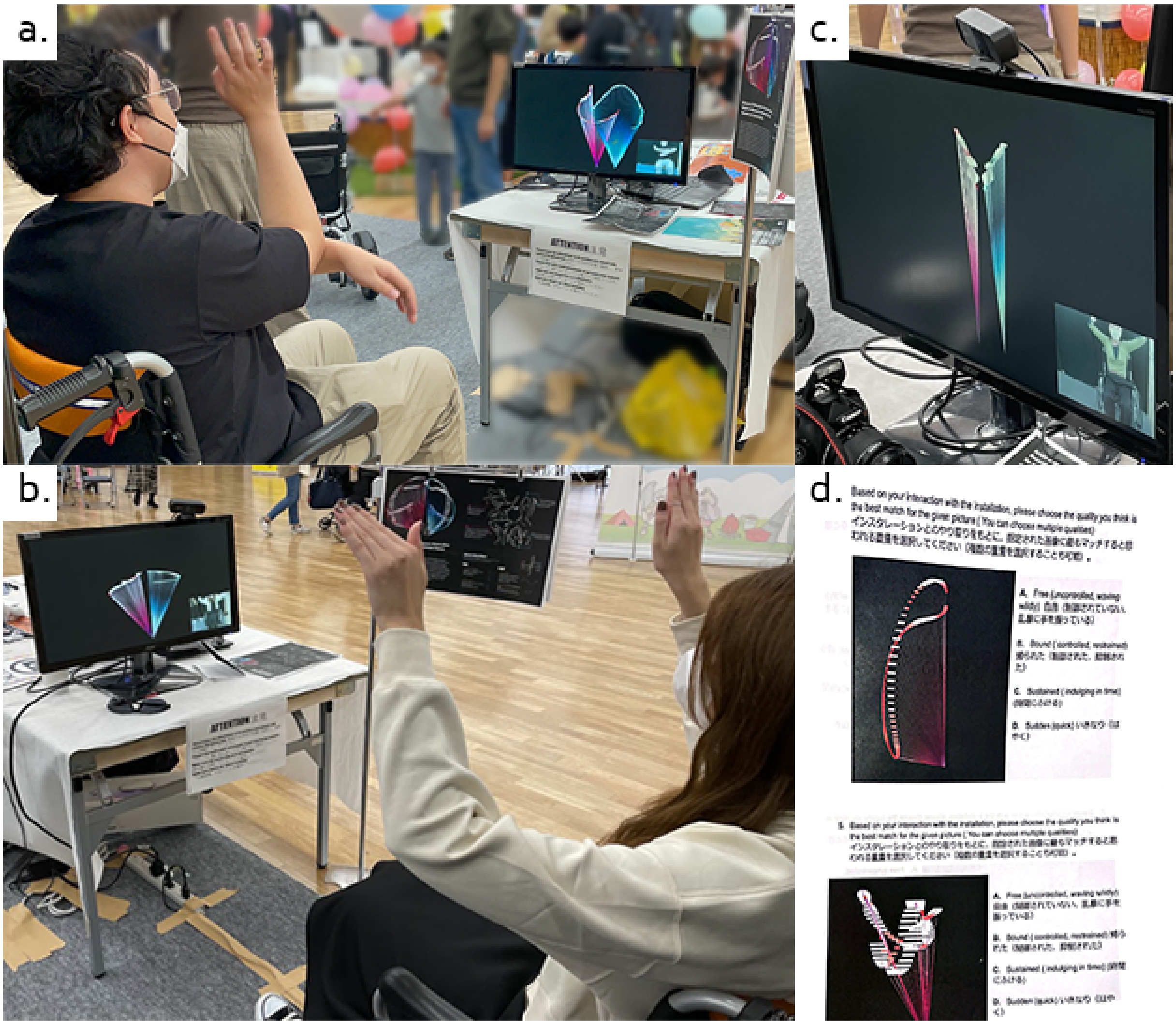

Figure 4.2: Pilot Study

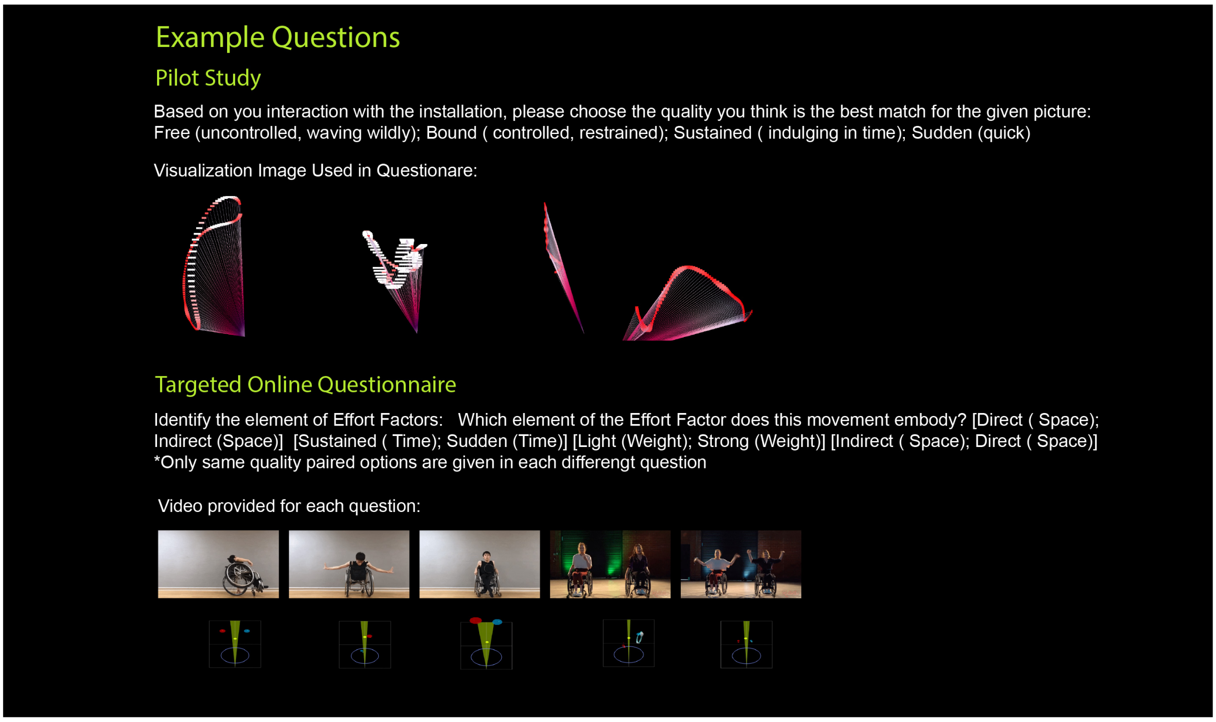

Figure 4.3: Example Questions

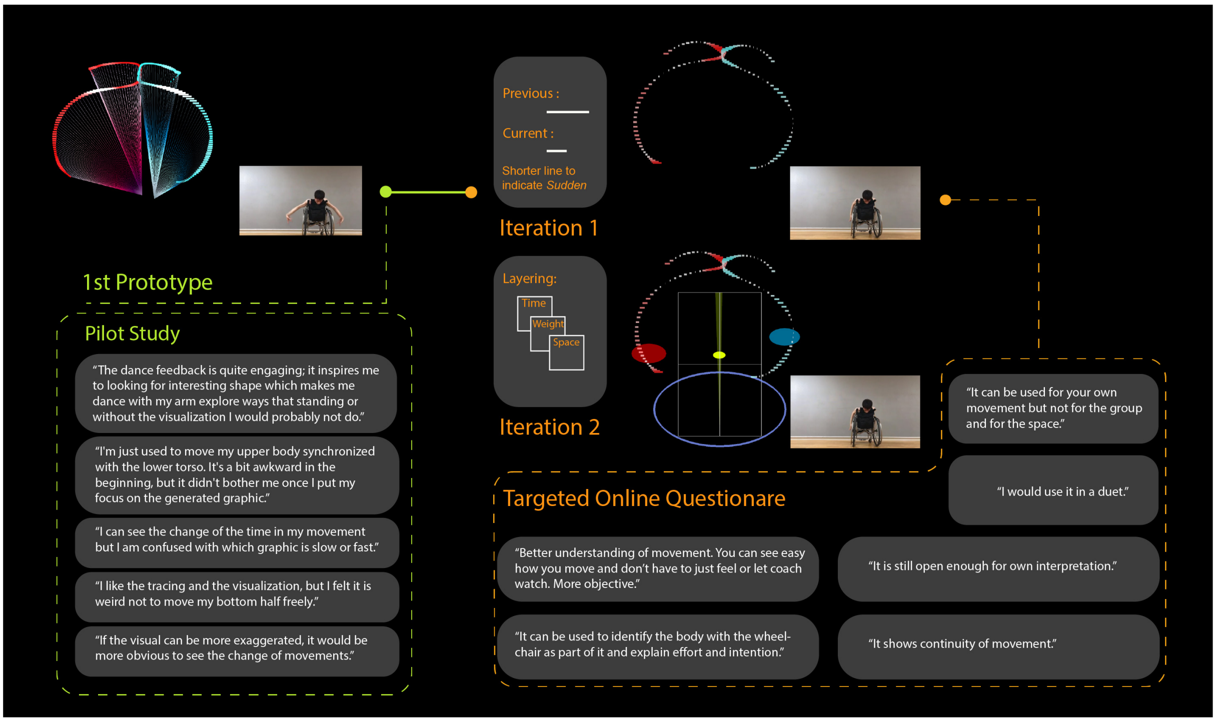

Figure 4.4: Iteration and feedback

Participants' Response

By employing a qualitative questionnaire during the KMD Forum exhibition, we were able to discern noteworthy findings regarding the impact of Effort visualization on first-time wheelchair dancers. The results indicated that the visualization facilitated their exploration of movement possibilities and enhanced their ability to recognize and comprehend the Effort *Time* (Figure 4.4). The participants reported that the visualization provided them with a valuable visual framework to understand and engage with the temporal aspects of their movements, thereby contributing to their overall dance experience. These insights shed light on the effectiveness and value of Effort visualization for novice wheelchair dancers in fostering movement exploration and temporal awareness.

> *"I'm just used to moving my upper body synchronized with the lower torso. It's a bit awkward in the beginning, but it didn't bother me once I put my focus on the generated graphic."*

> *"The dance feedback is quite engaging; it inspires me to look for interesting shapes which makes me dance with my arm and explore ways that standing or without the visualization I would probably not do."*

However, the findings also indicate that successful identification of the correct Effort quality within the system necessitates a learning process and familiarity. While the majority of participants were able to recognize the visualization of *Time*, particularly its temporal changes, the identification process still required cognitive effort. A subset of participants faced challenges in accurately determining the quality associated with *Time*. These results highlight the importance of thoughtful consideration and engagement, as some individuals may encounter difficulties in correctly identifying and comprehending the specific attributes related to *Time* within the visualization system.

Design Iteration

Based on feedback from the study, our visualization was refined as shown in Figure 4.4. To improve clarity, we minimized excessive visual elements. We replaced them with shorter lines to represent *Sudden* in Time and employed overlapping Effort visuals to present a comprehensive depiction of movement.

4.0.2 Online Questionnaire

To assess both the comprehensibility and artistic significance of our visualization, we administered questionnaires to a choreographer and three wheelchair dancers. By engaging these individuals, who possess expertise and experience in the field of dance, we aimed to obtain valuable insights regarding their understanding and interpretation of the visualization (see Figure 4.5).

Questionnaire Setup

Within the questionnaire, our primary objective was to gather pertinent information regarding the dancers' backgrounds, thereby fostering an understanding of their expertise and experiences. In addition, we tasked participants with identifying and interpreting the Effort components depicted within the visualization, allowing us to gain insights into their comprehension and perception of these elements. Moreover, participants were actively encouraged to provide written feedback, which played a vital role in our iterative process of refining and enhancing the visualization. Their valuable insights and suggestions allowed us to make necessary improvements and adjustments to the visualization based on their experiences and perspectives. To ensure transparency and accessibility, the complete questionnaires, containing detailed responses, have been included in the supplementary material accompanying this study.

Professionals' Questionnaire Response

Professional dancers have expressed their appreciation for the visualization, noting its invaluable role in providing objective feedback. They emphasize that it offers a unique perspective through which they can perceive and evaluate their movements. The feedback from these dancers confirms that the visualization not only facilitates technical analysis but also fosters a deeper understanding of artistic expression. This validation underscores its utility as a valuable tool for dancers to enhance their artistic practice and further explore their creative potential(Figure 4.4). In addition, professionals have expressed their desire to utilize these visualizations in real-time performances to represent their artistic intentions and facilitate objective evaluations. Their feedback highlights the potential for

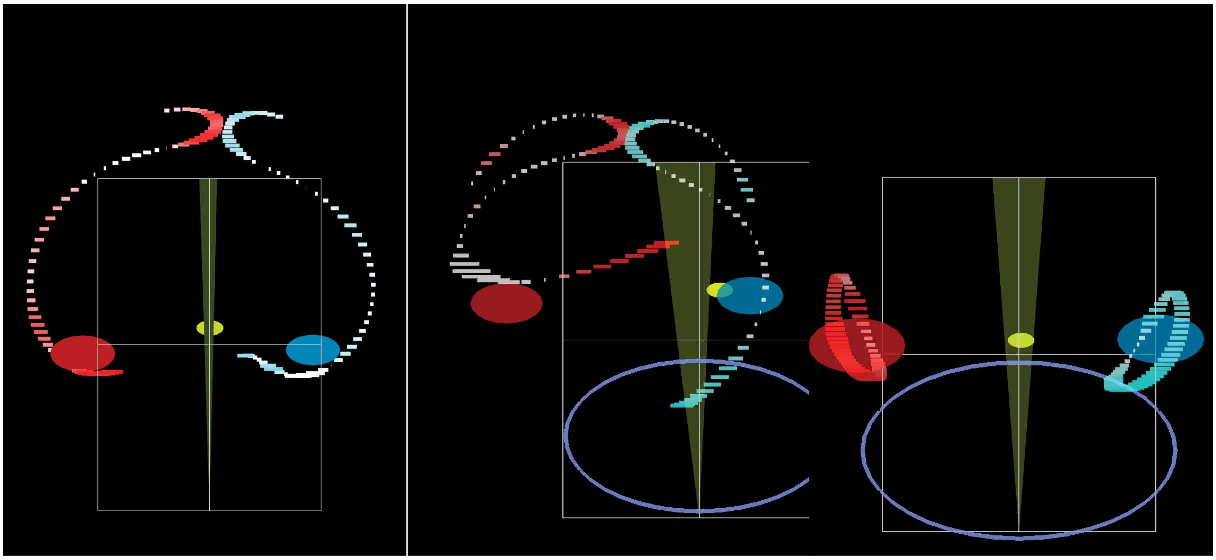

Figure 4.5: Visual Output

these visualizations to serve as dynamic tools that enhance the live performance experience, enabling dancers to showcase their intentions more effectively and providing a means for objective assessment and evaluation during the performance itself (Figure 4.4). Among the participants, two individuals mentioned suggestions regarding the visual representation of the dancer's body. They proposed incorporating a more objective approach by partially preserving the original body form within the visualization. Additionally, they emphasized the importance of including a visualization of rhythm to better identify and evaluate movement quality. Furthermore, one participant expressed a suggestion to expand the visualization solution to encompass multiple or grouped dancers. This recommendation implies a desire to extend the application of the visualization beyond individual dancers, allowing for a more comprehensive representation of collaborative or synchronized movements among multiple dancers.

4.0.3 In-depth Interview

The second stage of the evaluation encompasses conducting in-depth interviews with four esteemed professional wheelchair dancers hailing from France, Belgium, and Japan. These individuals possess extensive experience in various facets of wheelchair dance, including education, choreography, performance directing, and para-dance competition. Notably, among the participants in these interviews is Kenta Kambara, the choreographer and dancer of the Sun Dance. Through these in-depth interviews, we aim to gather nuanced and informed feedback on the system's efficacy, artistic significance, and potential impact on the wheelchair dance community.

Interview Process

Prior to the interviews, the participants were contacted via email and provided with consent forms outlining the data collection process during the interview. The interviews themselves were conducted in real-time using the Zoom platform, with the researcher and participants interacting face-to-face through video conferencing. The communication during the interviews was predominantly in English, with one interview involving an additional researcher who assisted in translating Japanese to English.

Firstly, the researcher commenced by delivering a concise introduction to the research topic and providing relevant background information. Subsequently, the participants were queried about their familiarity with Laban Movement Analysis (LMA) and other movement analysis systems. Out of the participants, only one individual expressed no familiarity with LMA, while the remaining participants demonstrated varying degrees of familiarity or awareness regarding LMA.

To ensure a consistent level of understanding, all participants were presented with a specific introduction to the Laban Movement Analysis (LMA) Effort theory. The introduction provided a standardized level of content, aiming to ensure that all participants had a clear comprehension of the basic description of Effort. This approach aimed to create a level playing field for discussions and analysis during the interviews, allowing participants to engage with a shared understanding of the Effort theory within the context of LMA.

During the interviews, participants were presented with a video clip showcasing the generated visualization from Kenta Kambara's Sun Dance choreography. The generated visualization was presented separately for each Effort quality, allowing participants to focus on and identify the specific Effort demonstrated without any distractions. Participants were then asked to identify the Effort quality based on their observations.

Following this identification process, the researcher presented a second video that showcased the visualization overlaid on the original dance video. This presentation aimed to solicit feedback from participants regarding the visualization system. By observing the visualization in conjunction with the actual dance performance, participants were able to provide valuable insights and opinions on the effectiveness, accuracy, and alignment of the visualization system with the choreography.

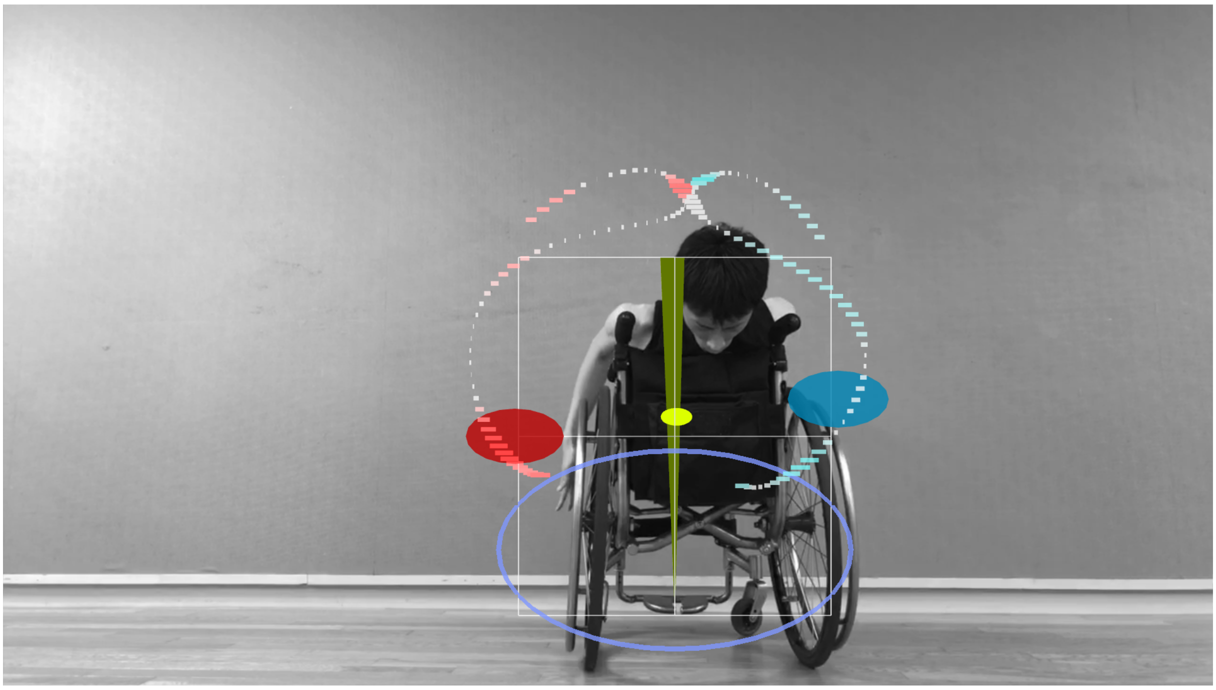

Figure 4.6: Visual Output

Interview Feedback

During the identification of Weight quality, three participants demonstrated a clear ability to identify the changes in Weight quality and accurately recognize the corresponding Effort. Interestingly, the original creator of the choreography made an intriguing observation during the evaluation process. He emphasized that there were instances where the body visually appeared stretched or expanded, yet the amount of force exerted increased, leading to a movement quality characterized as Strong in terms of Weight. This observation highlights the nuanced nature of movement analysis, where visual cues alone may not always align with the perceived level of effort or Weight quality, underscoring the importance of considering multiple factors when interpreting and identifying Effort qualities accurately. For example, when a dancer expand their upper limbs gradually, they might generate more force to keep the body gesture aesthetically appealing. Hence, this movement would be perceived as light visually, but the inner force is Strong.

In the identification of space quality, two participants can identify the change in Space quality, but most participants stated that they had a hard time deciding which Space quality (motion factor) the visualization is depicting. Participants expressed initial feedback indicating a perceived lack of significant changes in the visualization, leading to confusion and hesitation in accurately determining the quality of Effort. Furthermore, it should be noted that the absence of the wrist trajectory visualization in this particular interview had an impact on the participant's ability to identify and comprehend the Space Effort overall. These factors collectively underscore the importance of considering the participants' feedback and the influence of specific visual elements on their understanding and interpretation of Effort and Space qualities within the context of the study. Conversely, it is important to acknowledge that the participants in this study were relatively inexperienced with the new system and the visual language employed. This lack of familiarity likely influenced the outcomes and results of the study, highlighting the significance of considering the participants' limited exposure and understanding of the system when interpreting the findings.

During the feedback session, the participant brought up the limitation of the visualization of two-dimensional information which can distort the movements. This crucial aspect suggests on attention in future developments is the integration of the z dimension within the movement tracking system, as well as in the processes of feature extraction and visualization.

> *"One thing that's been bothering me is that I can only see the movements in two dimensions. But dance, it's always three-dimensional. And that's why I find myself hesitating when it comes to choosing the Effort quality because I just don't have a clear picture of what the en-*

> *tire movement looks like. It's like I'm missing out on an important piece of the puzzle. "*

Another frequently mentioned aspect by the participants is how can this movement quality visualization system work with multiple dancers. Can different abled dancers fit in or use the system as well? The participants often collaborate with differently abled dancers, which is the reason such concern was brought up. Wheelchair dance often integrates with another genre of dance or various abled dancers in performance and education, which offers another significant insight for future improvement.

> *"I think it would be interesting to have different dancers using it. Can it work for dancers that are not just in a wheelchair ? What if the choreography is a duo piece? "*

One participant raised an important point regarding her experience in dance training, highlighting the significant challenges she faces when communicating with dance instructors or choreographers due to the substantial differences in her wheeling condition compared to able-bodied dancers. This communication barrier arises from the unique physicality and movement capabilities associated with her wheelchair use, which necessitates a more nuanced and tailored approach to instruction and choreography. This observation underscores this system can potentially benefit from adopting an inclusive and adaptive approach.

> *"When I just started taking dance classes, I always had a hard time learning and transferring the technique in regular classes. It took me more time to practice and to understand the technique. "*

Participants further expressed the potential benefits of the proposed system in the context of dance education for wheelchair dance. They highlighted the existing limitations and inaccessibility of current wheelchair dance education, which often fails to adequately cater to the unique needs and experiences of wheelchair dancers. Moreover, participants emphasized that the field of wheelchair dance education is largely dominated by able-bodied dancers without a deep understanding or experience in disability dance. In this regard, the introduction of the proposed system holds promise as a valuable tool to bridge this gap, providing a more inclusive and accessible platform for wheelchair dance education and fostering a better understanding of the specific challenges and artistic expressions associated with disability dance.

4.0.4 Discussion

The objective of this research is to develop a visualization system based on Laban Movement Analysis (LMA) for wheelchair dance. The system aims to address challenges faced by wheelchair dancers, such as ableism and limited resources, to support the artistic expression of wheelchair dance. By utilizing motion tracking and pose-estimation technology with established LMA concepts, the system generates visual representations of movement qualities. The main critical question this research addressed is How can disability art, specifically wheelchair dance, effectively position itself within contemporary emerging art fields to maintain its artistic relevance while safeguarding its distinctive qualities? and to what extent can established dance methodologies, primarily developed for individuals with able bodies, enhance and enrich the practice of wheelchair dance? During the design and evaluation process, this research also explored various facets related to movement tracking for wheelchair dancers, the visualization of motion data in relation to artistic expression in collaboration with the artists, and the execution of the evaluation phase.

In the Crip theory, the principle of re-conceptualization of disability is the celebration of disability and the abnormality through practicing disability as a positive characteristic [9]. This design fosters inclusive movement analysis in HCI and challenges stigmatized ableism through assistive tools as artistic resources, opening an artistic perspective on engaging non-normative bodies. This research proposes that individuals involved in wheelchair dance, disability art, media art, and research, who aim to advance disability art, can derive advantages from adapting established methods like motion tracking or dance methodology to accommodate diverse body forms or abilities. Rather than modifying one's original practice, form, or ability to align with the prevailing approach, this approach recommends adapting existing methods to suit varying body forms or abilities. The incorporation of emerging technologies can extend the artistic achievements in disability art, such as enhanced expression, education, collaboration with different occupations, and exploration of creativity. Harnessing technologies from a human-computer interaction perspective can also eliminate the physical constraints many wheelchair dancers and disability artists are facing, such as the limitation of mobility, stigmatization of assistive tools, accessibility to venues, the pairing of partners, and costume consideration. Therefore, technology can potentially empower the positive transcending of wheelchair dance and disability art into a positive and aesthetic appreciation in current contemporary art.

Another factor in positioning disability art such as wheelchair dance is the practice of re-mapping and adaptation from established methodology or artistic evaluation. In this research, the solution explored with re-framing of LMA to wheelchair dancers. Evaluation with professional dancers suggests potential extensive study of this solution can focus on assisting wheelchair dance education, and hybrid education with differently abled dancers. The combination of established art methods augments the legitimization of wheelchair dance, which offers a new perspective on the positioning of disability art in contemporary art fields. However, this solution needs further exploration with experts in movement analysis, or LMA notators to ameliorate the re-framing process. On the other hand, disability rarely contains the exact same characteristics, which suggests that movement analysis, such as LMA, should take into consideration how to develop adaptable and flexible structures that can benefit differently abled bodies. To achieve this prospect, the participation of movement analysis experts, differently abled dancers, choreographers, and dance educators should be brought into a collaboration to evaluate and explore possibilities.

Additionally, the development of movement analysis for individuals with diverse abilities can bring further benefits to movement tracking and pose estimation methodologies. The current implementation of movement tracking in this research lacks the inclusion of three-dimensional data. This limitation arises from the utilization of video input in a two-dimensional format, while the employed MediaPipe pose estimation restricts the prediction to the z dimension. As dance and movements are three-dimensional spatial-temporal experiences, it is important to embody such experiences in three dimensions to communicate movements and express their full intention holistically. Meanwhile, video-based input and pose estimation can only capture the contour or the limited positional data or trajectory of movements which can be fragmented and misguiding. The complexity of movement and its relation to body dynamics requires hybrid and holistic capture that goes beyond singular positional data, especially in capturing and extracting data for Weight quality. In the future development, movement tracking for wheelchair dancers can take a more hybrid approach, where dynamic and haptic data should be considered. However, when applying movement tracking, the mobility of the artists and the orientation of assistive tools should be taken as the priority to enhance the artistic aesthetic. It is important to acknowledge that the accessibility of such technology should also take into consideration factors such as affordability and flexibility to accommodate different dance practices and body forms.

Visualization also contributes as a vital element of movement expression in this research. Visual language harness the indexicality of various visual quality. The current visualization focuses on a preassigned visual index, such as length, color, and scale change. However, movements possess inherent complexity, and within them lie intricate intentions and varying degrees of quality, where it requires profound indexicality to represent their diversity. Therefore, this research also proposes that future approaches can focus on the creation of visual language to meet the complexity and diversity of movement quality. On the other hand, the created visualization should also equip enough flexibility for the dancer or artist to control and customize based on their creative concept. In our vision of future applications, we anticipate the adoption of a co-creation approach involving the integration of visualization systems, leveraging advancements in image generation, intelligent systems, and natural language processing. This integration aims to augment and enhance the solution through synergistic interactions among these technological developments.

In conclusion, the integration of emerging technologies has the potential to enhance artistic achievements in disability art, improve accessibility, and empower wheelchair dancers. Furthermore, the research highlights the need for collaboration with movement analysis experts, differently abled dancers, choreographers, and dance educators to evaluate and explore possibilities. Future development should consider incorporating three-dimensional data, hybrid capture methods, and a more nuanced visual language to accurately represent the complexity and diversity of movement qualities. Ultimately, the co-creation approach involving visualization systems, image generation, smart systems, and natural language processing holds promise for further enhancing the solution and advancing the field of wheelchair dance within the contemporary art landscape.

Chapter 5
Conclusion

The visualization solution developed in this study offers a novel approach to creating a visual notation for Laban Movement Analysis (LMA) Basic Effort in the context of wheelchair dancing. By integrating the concept of the wheelchair as an extension of the body, along with principles of body reconstruction and experiential aesthetics in dance, our visualization solution aims to express the artistic value inherent in wheelchair dance. Based on the pilot study, online questionaires and indepth interviews, the resulting visual notation of LMA Basic Effort provides an objective means of interpreting movement quality, thereby facilitating the exploration and evaluation of wheelchair dance movements. This innovative approach not only expands the artistic potential of wheelchair dance within the professional dance community but also enhances the understanding and engagement of wheelchair dance among broader audiences and applications.

The design fosters inclusive approach of body form and movements in HCI and challenges stigmatized ableism through assistive tools as artistic resources, opening an artistic perspective on engaging non-normative bodies. We argue that the proposed solution extends motion tracking and movement data processing to diverse body-forms, where emerging technology, such as diverse motion capture methods can foster holistic LMA in wheelchair dance. In a broader perspective, HCI development in inclusive technology should consider the adaptivity to various body forms and the uniqueness of disability. This design has potential applications in HCI for performance, digital education, and design bodily interaction for assistive technology. Future development could explore incorporating multiple dancers and integrated dance groups.

The objective of this research was to promote the integration of disability art into the mainstream art world by employing artistic methodologies in wheelchair dance. Preliminary testing of the developed system has shown promising outcomes, indicating its potential to enhance movement exploration, education, performance, and communication for artists utilizing wheelchairs. Future implementations will delve deeper into the theoretical aspects of disability art, exploring its impact on artistic legitimacy within the field. The visualization of Laban Movement Analysis (LMA) movement quality serves as a bridge between LMA methodology and wheelchair dance, enabling the expression of artistic value that extends beyond physical disability.

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Appendices

A. Questionnaires and Consent Forms

Pilot study questionnaire and consent form

https://drive.google.com/file/d/1v8OUvhCIHg5owiiJzHrDVRMSkUkQTtI4
/view?usp=drive_link

Online Targeted questionnaire and consent form

https://drive.google.com/file/d/1c54gKcjpTnJArmdKU7jr3RC1eH99kn6V
/view?usp=drive_link

B. Touchdesigner Development

See Figure 3.4