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The Tangibilization of Indigenous Dances and the Rehearsal of a Similarity Model for Quantitative Analysis of Movement[1]

La tangibilización de las danzas indígenas y el boceto de un modelo cuantitativo de análisis de similitud de movimiento

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RESUMEN

Este artículo explora herramientas de variada asequibilidad dentro del campo de las tecnologías informáticas de reconocimiento del movimiento humano como un medio para responder a la actual falta de protección de las danzas indígenas. Tras una descripción teórica general de las nuevas tecnologías desarrolladas para procesar el movimiento humano, incluida la captura de movimiento, la visualización de video y la visión por computadora, este artículo ofrece un recuento de sus aplicaciones prácticas para el campo de la danza. Esta es la experiencia del Movement Similarity Project realizado en el RITMO Centre de la Universidad de Oslo, aquí analizado como estudio de caso, en el que la tecnología de captura de movimiento se utilizó para medir cuantitativamente el grado de similitud entre dos danzas. Las posibilidades, limitaciones y direcciones futuras de estas tecnologías son evaluadas de acuerdo con su capacidad para salvaguardar las danzas indígenas.

PALABRAS CLAVE

Danza, indígeneidad, Humanidades Digitales, reconocimiento del movimiento humano, patrimonio cultural inmaterial.

ABSTRACT

This article explores several tools of varying viability within the field of computational technologies for human motion recognition as a means of responding to the current lack of protection afforded to indigenous dances. Following a general theoretical overview of new technologies developed to process human movement, including motion-capture, video visualization, and computer vision, this paper offers an investigation into the practical applications of such technology when applied to dance. The Movement Similarity Project at the University of Oslo's RITMO Centre is explored as a case study, in which motion-capture technology has been utilized to measure and quantify the degree of similarity between different dance recordings. The possibilities, limitations, and future directions of these technologies are evaluated according to their ability to safeguard Indigenous dances.

KEYWORDS

Dance, Indigeneity, Digital Humanities, Human Movement Recognition, Intangible Cultural Heritage.

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1. BRIDGING NEW TECHNOLOGIES AND INDIGENOUS CULTURE

> The examples I have hinted at of indigenous peoples claiming copyright in countries where they form a disadvantaged minority may indeed point to a future where indigeneity certainly does not fade away in the face of modernization but, on the contrary, becomes more sharply focused and more effectively advanced (Stanley, 2007, p. 17).

The term indigeneity is often discursively assumed to represent the reverse of modernity. For indigenous communities, the postulation of modernity as fundamentally opposed to indigeneity has at times proven expedient to resist the alteration of traditional ways of life and the resistance to adapt to premises of individualized authorship and discreet cultural production, as put forward by international legal frameworks of intellectual property. This opposing binarism between indigeneity and modernity, however, remains rooted in essentialism; hindering Indigenous communities from securing the technological tools required to make tangible cultural creations under traditional premises of interrelated creativity and collective ownership. But before destabilizing this harmful opposition, we propose to critically approach how indigeneity in itself is regarded, through international law bodies like the General Conference of the International Labour Organization:

> People in independent countries who are regarded as indigenous on account of their descent from the populations which inhabited the country, or a geographical region to which the country belongs, at the time of conquest or colonization or the establishment of present State boundaries and who, irrespective of their legal status, retain some or all of their own social, economic, cultural and political institutions (1991, Art. 1b).

The ensuing question would be then, how can indigenous populations continue to uphold cultural institutions and practices when the international regimes aimed at protecting creativity follow contrasting epistemological and conceptual premises? For instance, Indigenous and non-Indigenous peoples are required to fix their creative output on a tangible medium, in order to protect their rights through Intellectual Property Regimes (IPRs)[2]. Pervasive stereotypes of Indigenous peoples foreclose them from engaging with new technologies of tangibilization by relegating them to a separate temporality, as if "what is different about them remains tied to traditional pasts, inherited structures that either resist or yield to the new but cannot produce it" (Clifford, 1988, p. 5). The digital divide and unequal conditions of access to resources and new digital platforms by Indigenous populations make it harder to comply with the fixation requirement set forth by IPRs, in turn reifying the said discursive distance between indigeneity and the technological tools of modernity.

[2] The three criteria that commonly define the scope of IPRs include innovation, authorship, and fixation.

Discourses surrounding Intangible Cultural Heritage (ICH) or Traditional Cultural Expressions (TCEs)[3] from indigenous communities (used interchangeably in this paper) "cannot be somehow placed in a parallel world totally unlinked to the modern digital networked environment, whose reach will only become greater over time" (Burri, 2008, p. 226). New technologies are, indeed, already shaping the ways in which ICH circulates and is produced, and the modernization of information and communication technologies has already had an impact on Indigenous livelihoods. Scholar Mira Burri states that:

> although we do not underestimate the fact that many indigenous communities tend to be materially poor and that the digital divide is a reality, anecdotal and empirical evidence shows that Indigenous peoples have been active users of the Internet for quite some time now (albeit certain communities reject it) (2008, p. 229).

By understanding indigeneity not necessarily as at odds with digital technology, significant resonances may start to be drawn between the nature of traditional knowledge and contemporary technological developments. The Internet may in fact serve as "an ideal match for Aboriginal[4] [sic] tribes, providing the necessary economy of scale to support electronic publishing [that] can support an admixture of audio, video, and text, transcending the print medium" in ways that are "ideally suited to the oral story-telling traditions of the Aboriginal Community" (Zellen, 1998, p. 148). Other discussions similarly point to the resemblance between community-driven forms of creative production within Indigenous populations and those seen on the World Wide Web, in terms of challenging individual authorship of cultural production. For instance, Daniel J. Gervais encounters a correspondence between Indigenous epistemologies and interactive forums compiled by online networks:

> Resulting compilations may look like copyright material, but no identifiable author, no one, including legal persons, has true control over or responsibility for the result. Each participant can, at the time and place that he or she chooses, add whatever he or she wants. These planetary happenings resemble folklore because the creative process is similar only incredibly accelerated by this new tool (2003, p. 488).

Since we are dealing here not with Indigenous ICH or TCEs in general, but with dance in specific, it is relevant to outline some definitions. Indigenous dance can be defined as a bodily form of creativity held by peoples whose deep relationality with a specific territory informs their social, economic, and cultural understandings. However, there is another stream of thought that can also

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[3] The UNESCO (2003) convention has defined intangible cultural heritage as "the practices, representations, expressions, knowledge, skills–as well as the instruments, objects, artifacts and cultural spaces associated therewith–that communities, groups and, in some cases, individuals recognise as part of their cultural heritage". According to the same convention, such expressions of ICH can be manifested in the form of: (a) oral traditions and expressions, including language as a vehicle of the intangible cultural heritage; (b) performing arts; (c) social practices, rituals and festive events; (d) knowledge and practices concerning nature and the universe; and (e) traditional craftsmanship. An analogous definition of ICH can be found in the developments of the World Intellectual Property Organization (WIPO) under their analytical category of Traditional Cultural Expressions (TCE). Such expressions may comprise pre-existing materials dating from the distant past that were once developed by "authors unknown" through to the most recent and contemporary expressions of traditional cultures, with an infinite number of incremental and evolutionary adaptations, imitations, revitalizations, revivals and recreations in between.

[4] The term *aboriginal* is less common in American or European scholarship on indigeneity but is a term that circulates broadly in the Australian context.

assist with the conceptualization of Indigenous dances. This alternative strategy does not rely on combining two previously known concepts (indigeneity and dance), but rather describes Indigenous dance in terms of the stories it tells, the theories of embodiment it enacts, and the familial and tribal connections, processes, dedication, and intention that they enact (Murphy 2007, p. 7).

To further challenge the disadvantageous opposition between indigeneity and modernity, special attention needs to be given to the establishment of modern dance itself. Recent scholarship has drawn attention to various examples of how Indigenous dance practices have been misappropriated for the establishment of modern dance in the West. Prominent choreographers in the history of modern dance, including Ruth St. Denis, Ted Shawn, Martha Graham, and Lester Horton, either copied, mimicked, or discursively framed their work through ideas referencing Native American or Indigenous cultures (Desmond, 1991; Geduld 2010; Murphy 2007; Kraut, 2015). Similarly, Torsen and Anderson describe how for decades "the intellectual property rights of Hopi have been violated for the benefit of many other, non-Hopi people," including the misappropriation of "choreography from ceremonial dances [that have] been copied and performed in non-sacred settings" (2010, p. 76). According to a report published by the World Intellectual Property Organization, adaptations of the *sierra* dance of Peru and *hakas* of the Maori people have likewise raised concerns about the rights of Indigenous communities and the protection of their cultural expressions (2002). Misappropriation of the Ka Mate, a *haka* of the Maori people in New Zealand, has received substantial attention due to it being used in an Italian Fiat commercial without permission or compensation (Frankel, 2014). These examples describe a pattern of how Indigenous dance forms have fed a modernity that continually fails to credit, consult, or compensate the communities from which they were extracted. Forms of ICH such as dance keep being at risk of misappropriation today, sometimes even so more because of new digital technologies. For example, a Hungarian choreographer recently used video material available on YouTube to learn the *Kawel Tahiel* dance, an ICH expression traditionally held by the Mapuche people located in southwestern Argentina and southern Chile. This case drew the attention of Mapuche representatives who claimed their cultural expressions were exploited and decontextualized as they were showcased by the choreographer at KunstenFestivalDesArts, one of the most reputed dance festivals in Europe (Millan, 2020). To dispute these forms of unauthorized uses of culture and prevent future iterations, Indigenous communities require tools that can substantiate claims to ownership and establish choreographic similarity of materials appropriated across digital spaces.

This text seeks to introduce several tools of varying levels of viability within the field of computational technologies for human motion recognition to explore how they may protect Indigenous dances and revert their state of vulnerability. The term 'new technologies' is herein deployed as an umbrella term for digital tools of human motion recognition through computerized methods, in our case powered by motion-capture and similarity algorithms. This definition targets the question Burri (2008) poses about "how the changed (and changing) digital environmental influences [...] and whether (and how) one could coherently and efficiently provide for the protection and promotion of TCE in this environment" (p. 226). Within this changing digital environment, technologies of human motion recognition and motion-capture continue to gain relevance as the need for improving accuracy in the capture of human movement grows across diverse fields.

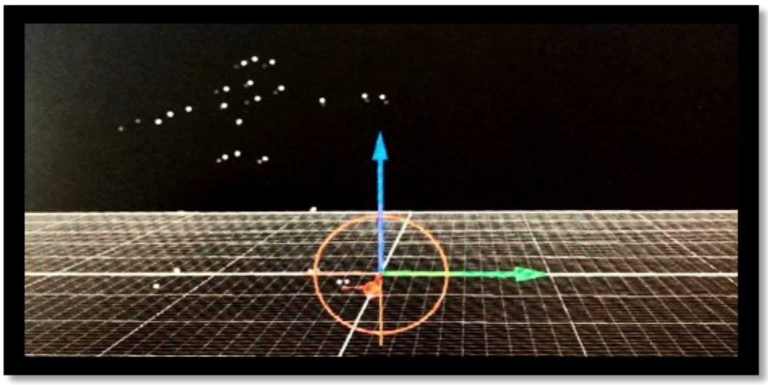


Figure 1. Visual representation of a motion-capture recording.
Source: Own work.

Motion-capture provides unique strategies for protecting Indigenous dances when compared to standard video recordings. Motion-capture is the all-encompassing term for describing several computational methods that "track and record the body and its motion in space over time" (Jensenius, 2014, p. 2). This particular technology achieves highly precise measurements of human movement by abstracting it into markers within an x, y, and z space. This abstraction renders invisible the identity of the person moving during the recording as seen in Figure 1, which might be suitable for communities that intend to hold collective ownership over their cultural expressions, rather than enshrining individual authors. Choosing to recognize and compensate only individual authors, as often required by IPRs, can promptly dismantle the communal dynamics of creative production in many Indigenous cultures.

A critical consideration must be made in every step of designing strategies to protect Indigenous dances to avoid generating new problems alongside those they intend to remedy. Michael F. Brown (2005) notes that "if global cultural diversity is preserved on digital recording devices while the people who gave rise to this artistry and knowledge have disappeared, then efforts to preserve intangible property will be judged a failure" (p. 54). That is to say, the aforementioned abstraction that motion-capture methods achieve between the identity of the dancer and the dance itself must work to the benefit of Indigenous communities and prevent indirect impositions of Western notions of individual authorship. Indeed, this consideration of motion-capture's multiple possible effects is critical given other forms of abstraction whose results can be devastating:

> And even if traditional knowledge preservation is "inherently" proclaimed as a policy goal, such as in Brazil and the African Model Legislation, they understand it to be a knowledge stock of high "socio-economic value", which should be transcribed, documented, stored and utilized in digital databases. Thus, they tend to miss the goal of protecting the processes that lead to the generation of knowledge (Teubner and Fischer-Lescano, 2008, p. 4).

Conservation as the formalization and abstraction of cultural products and practices that neglect the communities that generate such knowledge is not only a form of neocolonial erasure but is also unsustainable. If the culture bearers and social relations that presuppose such knowledge are not taken into consideration in strategies that purportedly safeguard Indigenous practices, the documentation of such knowledge then serves as a eulogy. Miguel Escobar Varela and Luis Hernández -Barraza explain that “the availability of technological tools should not be used to the detriment of the historical and ethnographic analysis of dance” (2020, p. 163). Rather than prioritizing one method over the other, dance data from both “oral histories and biomechanical analysis” work complementarily to “document both fixity and change”. Accordingly, the questions that guide the following section are not posed with the intention of identifying unequivocal solutions, nor do they assume total objectivity of computer-based methods for the study of dance. Rather, this research report recognizes the interplay between technological tools and human input from which results are determined to assess both the possibilities and limitations of any computerized similarity model.

To frame these discussions within the scope of interest, it is important to consider how the interplay between Indigenous cultures and new technologies might prevent the misappropriations of dance across the digital space. For this reason, it is first necessary to identify what exactly is being misappropriated when dance in the form of data is circulating across the digital space. Then, clarification is required in terms of the appropriate method to tangibilize dance. The tangibilization of dance described here is designed to be quantitatively measured through a computerized method. To deal with these queries, section 1 offers an introduction to motion-capture technology and its variations, along with several other computer-based tools used to analyze dance. Section 2 offers an account of the practical applications of motion-capture within the framework of the movement analysis initiative, the Movement Similarity Project.

2. OVERVIEW OF MOTION-CAPTURE TECHNOLOGIES, VIDEO-VISUALIZATION TECHNIQUES, AND COMPUTER VISION AS A MEANS OF STUDYING AND APPROACHING INDIGENOUS DANCE

While new highly detailed methods of recording and studying dance are often evaluated against the overall goal of obtaining objective renditions of kinetic material, in the context of this article the usage of technology for human movement recognition is aligned with an urgency to aid Indigenous communities in establishing ownership of their materials and protect them from misuse. To consolidate such a connection, one must first establish for which purposes Indigenous communities might utilize new technologies. IPRs reward a person with the means to fix a cultural tradition regardless of whether or not they belong to the community of its traditional bearers. As a result, any development in the tools through which human movement is recorded needs to always be traversed by a concern for affordability and accessibility. New technologies thus present an opportunity to fix creativity over a tangible medium and consequently establish ownership, in order to expand the protection afforded to Indigenous dances under international legal frameworks. Similar concerns surrounding other formats of fixation or tangibilization establish the importance of considering who uses these tools:

> Indigenous cultural traditions are mostly oral and may have never been recorded in any material form whatsoever. Indigenous material expressions that do occur are often intended to be temporary, such as those connected with ceremonies and celebrations. Many indigenous oral traditions have been translated and published in printed form by non-indigenous authors who then themselves receive the benefits of copyright protection (Paterson and Karjala, 2003, p. 639).

The documentation of Indigenous cultural practices in fields such as ethnomusicology has a long history of misappropriation and extraction that has resulted in ethnographers gaining ownership over recordings of Indigenous cultural practices only because they were the first ones to fix them upon a tangible medium. In this sense, the digital divide in Indigenous communities is worsened as much by a lack of access to technologies for fixing artistic creations as it is by IPRs' privileging of tangibility in their assessment of ownership, regardless of who the actual creators of the practices in contention are.

In addition to archiving practices, there are further reasons to start considering new technologies as methods of safeguarding the interests of Indigenous peoples. When it comes to cases of misappropriation of their dances, Indigenous communities require tools to adequately display kinetic content for decision-makers to perform proper examination on any cases of misappropriation. In other words, alternative ways to display the body and its movements are needed. Scholar and researcher Alexander Refsum Jensenius writes that:

> visualization of human body movement has been a challenge for artists and researchers for centuries […] Since movements happen in space over time, they are not directly representable in two-dimensional displays on paper or screen. A key challenge then is to create displays that can effectively represent both temporal and spatial aspects of movement sequences (Jensenius, 2013, p. 54).

These representations, with enhanced affordances to portray the conditions of movement, are saliently required for Indigenous communities for documentation and contestation of cases of misappropriation.

The expanded interest in human movement has been translated into innovative ways of documenting, recording, comparing, and studying it with the assistance of computer-based systems. Precision, accuracy, and accessibility represent a few of the considerations that shape these different methods of studying bodies in motion. In the field of dance, movement can be recorded, represented, and taught through text-based descriptions, Labanotation, or video. Researchers in this field Kico et al. suggest that "the use of text documentation information about dance and its cultural significance can be presented, but in such a case, there can be a lack of movements and different dance styles. On the other hand, videos can easily present movements, finding, though, difficulties in successfully presenting additional information about each dance" (Kico et al., 2018, p. 2). These considerations surrounding how dance should be fixed suggest two parameters. There is an array of ways to approach and analyze human movement, and each of these ways offers a certain range of possibilities and limitations that make them tailored to cover some tasks and not others. Secondly, the set of new technologies developed to process human movement, including motion-capture, and video-visualization techniques are not the exception when it comes to having a limited range of analytical scope.

> What many people refer to as "motion-capture", can more precisely be described as optical, infrared, marker-based systems. Such systems usually consist of at least six cameras positioned around the capture space. Each of the cameras contains a ring of infrared light sources, and this infrared light is reflected on small markers and captured by the cameras. The system then calculates the exact position in space based on triangulating all the marker positions from each individual camera. The end result is a three-dimensional tracking of the markers in space, often captured at high speeds (more than 100 Hz) and at a high spatial resolution (in the range of millimeters). The captured points can be visualized directly or used as the basis for further analysis (Jensenius, 2018, p. 16).

Different variations of motion-capture systems may not be based on the use of cameras, but instead include sensor-based systems, which, for example, can incorporate acoustic devices or accelerometers. The high performance of these systems has caused them to not only find applications in commercial industries, such as in the production of big-budget animation movies but also to emerge as a rich field of exploration for academics and researchers. With interests ranging from human-computer interaction to law enforcement, the level of precision in motion-capture' offers a great deal of potential to record and display human movement in unprecedented ways. Additionally, recent developments are transforming this once-inaccessible technology into a considerably inexpensive option, which is a crucial factor if its applications are expected to benefit historically marginalized populations, including Indigenous communities. Commenting on the possibilities afforded by the Kinect Sensor, a complementary device manufactured by Microsoft for use with one of its most popular video game consoles, Kico et al. (2018) note that "many scholars used the Kinect sensor as a low-cost sensor for motion-capture as it provides real-time 3D skeleton tracking in dark and bright indoor areas (since it uses infra-red)" (p. 6). There are other options that likewise remain promising for increasing access to these technologies for Indigenous populations. For example, OpenPose (Cao et al., 2017) is an online portal for free motion-capture recognition that can identify human poses in real-time using a standard 2D camera, made possible by the embedding of machine learning technology in a web-based environment.

Assisted by researchers, public agencies, academic institutions, and non-profit organisations, constant, sustained, and participative documentation of Indigenous dances through motion-capture could bolster the defensive protection of TCEs[5], particularly if paired with innovative ways to visua-

[5] The defensive protection of TCEs (Traditional Cultural Expressions) is defined by the Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore (IGC) as "the protection of TCEs against the obtaining of IP rights over the TCEs or adaptations thereof" (IGC, 2018, p. 19).

lize recorded materials. There has also been increasing awareness of the need to preserve traditions through technology among the bearers of Indigenous rituals and ceremonies themselves. Nick Stanley, for example, notes how a Chambri elder, named Thadeus Yambu, has been engaging researchers and new technologies to document ritual procedures and preserve the Chambri way of life, which he believes is currently endangered by the decreasing interest of younger community members in maintaining these ritual practices:

> Unless these rituals were recorded in a scientific way, there would not be an adequate record to show in a court of law to claim copyright for the event and its constituents. But for magistrates the ritual knowledge had to be recognizable in generic terms that they could relate to other examples from elsewhere. This was what Yambu was also attempting to provide in his documented performance (Stanley, 2007, p. 11).

This twofold richness of the recorded material as both a method of cultural preservation and legal protection may be expanded or diminished by the specific media employed. The saliency of the material's features, including its details and visibility, is not only determined by the recording method but also by its format of representation. It follows that the most effective material is that which can be displayed in the most varied ways. Jensenius (2018) has been invested in creating "alternate displays from video recordings […] to develop new visualizations to be used for analysis" of human movement (p. 10). This led to the creation of a set of computer-based tools consolidated in the software Musical Gestures Toolbox, whose functions include the ability to produce visual and sonic reports from both standard and motion-capture videos of people dancing. By revealing in-depth information about dance from a multi-layered and quantitative perspective, these video-visualization techniques add dimension to what might have appeared before as just movement:

> [The software] addresses different needs for representing body movement at different temporal levels. Motion history images may be used to visualize movement trajectories over short periods of time (up to around 5 seconds) or for longer sequences when combined into motion history keyframe displays. Motion average images can display the spatial distribution of entire recordings, but with no reference to temporal development. Motiongrams, on the other hand, can be used to display the spatiotemporal development of longer movement sequences—from a few minutes to several hours. Separately, or preferably together, these different displays are useful as movement summaries, for navigation and in comparative studies (Jensenius, 2013, p. 59).

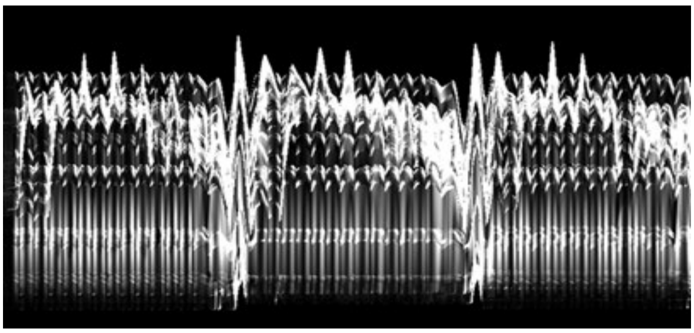


Figure 2. Motiongram created through the Musical Gestures Toolbox offers a snapshot of the trajectory of the movement as it unfolds in space. Source: Own work.

These expanded possibilities of rendering and studying the features of dance intersect with the need for strong management plans to protect the privacy of the data recovered and prevent misappropriation resulting from the excessive availability of sensitive material. Some projects have demonstrated how protocols regarding the sharing of information can be established with Indigenous communities to present their cultural practices in appropriate ways[6]. It must be remarked, however, that most of the results obtained by the video-visualization techniques from the aforementioned Musical Gestures Toolbox are materials that are not necessarily intended for large audiences. Rather, these technological tools allow researchers to carry out in-depth investigation of the patterns and structures embedded in the dances analyzed.

Figure 3. Motion history image highlighting the portion of the body most prominently involved in the movement.
Source: Own work.

> Surprisingly enough, body sensors, cameras, and other high-end pieces of hardware are used for the precise recording of a procedure, which is normally considered a technology-free expression of dancing groups. Using these technologies, accurate folk dancing representations can be produced that will later make the transmission of knowledge easier. The result of such processes is continuously proven to provide new ways for dance teachers, choreographers, game developers, and more to communicate detailed dancing elements to learners, dancers, and gamers, respectively (Kico et al., 2018, p. 17).

The usefulness of these methods is never untethered, however, from culturally sensitive sharing protocols and community-driven channels of diffusion, given that these technologies have also been employed in the past to facilitate the very misappropriation of traditional knowledge. Because these ethical questions develop in close ties with the technical affordances of these technologies, the following section recounts the experience of practical engagement with motion-capture and similarity algorithms, and the possibilities and limitations they have for protecting Indigenous dances.

3. THE MOVEMENT SIMILARITY PROJECT

At the RITMO Centre (Interdisciplinary Research Centre on Rhythm, Time and Motion) of the University of Oslo, musicological, psychological, and informatic methods are employed to study

[6] For an example of data management within the National Museum of the American Indian according to agreed-upon protocols, see Hunter, J., Koopman, B. and Sledge, J. *Software Tools for Indigenous Knowledge Management*. Available at: https://www.museumsandtheweb.com/mw2003/papers/hunter/hunter.html

rhythm as a fundamental property of human cognition, behavior, and culture. Within this framework, the Movement Similarity Project was established to explore new potential technological tools for the prevention of the misappropriation of Indigenous creativity. The question of how new technologies could analyze, visualize, and establish a degree of similarity between two distinct dances in contention, formed the cornerstone of this initiative. Measuring similarity was not deemed as an end in itself but as a tool to support Indigenous peoples' claims of misappropriation of their ICH. In other words, the project set out to discover how computer-based systems for human movement recognition could potentially assist decision-makers in establishing a case of misappropriation of Indigenous dances through empirical and quantitative methods.

3.1. Rationale of the project

The similarity between any two dances arises at the precise moment that one chooses to juxtapose and compare them. The level or degree of such similarity could be assessed based on macro traits such as the type of dance that is presented, including round dances, chain dances, couple dances, or solo dances. Similarity can also be assessed according to the degree of correspondence in the specific ways in which dances are structured, as in choreographies, sections, and phrases. Moreover, there is the potential to focus on resemblances through detailed observation at more granular levels, if individual steps and gestures are analyzed. The nuanced perspective that these various degrees of inspection offer in combination is significant, given that two dances might seem similar on one level while at the same time presenting clear dissonances on another. In addition, the degree of similarity between any two dances becomes intertwined with the scope and method employed to compare them. Thus, it becomes critical to assess the categories and parameters that any analysis system relies on to calculate the level of correspondence. In the case of this study, the style in which movements are performed was foregrounded as one of two main attributes, rather than the singularly definitive aspect, in determining the resemblance between two dances. Along with the style of movements, the content of the steps themselves was considered and measured to produce a quantitative report of similarity.

Before experimenting with methods and metrics of comparison, it was necessary to first secure a cluster of recordings of different people dancing the same choreography in varying ways across several takes. The reasoning behind this is that only by stabilizing the steps or semantics of the dance could the stylistic traits in them be further isolated. Ten subjects, most of them people affiliated with the Centre, were invited to participate in the recording sessions. Participants did not need to possess any previous dance training or experience, given the fact that the pre-established and elemental sequence of movements chosen for the study was not expected to be physically demanding or difficult to learn. Each of the ten participants performed the given choreography across ten separate recordings and for each take, three repetitions of the choreography were requested. Participants faced the control room for the first take, then turned ninety degrees for the second take, and rotated another ninety degrees to face the wall opposite the control room for the third take. Facing the control room does not mean facing the camera, since a set of thirteen infrared cameras were placed in various locations in the motion-capture laboratory and operated with Qualysis equipment. Additionally, a standard video camera was included to film the experiments, whose video output signal was connected to the same centralized system so that researchers could utilize the synchronized perspective of both standard video and motion-capture data.

Each participant wore a complete motion-capture bodysuit with twenty-three markers. The position of the markers was based on the number of points and different locations on the body required to render a comprehensive human silhouette that could easily be traced during post-processing. The position of markers was consistent across all of the recordings and subjects to dependably and effectively portray the pre-established movements.

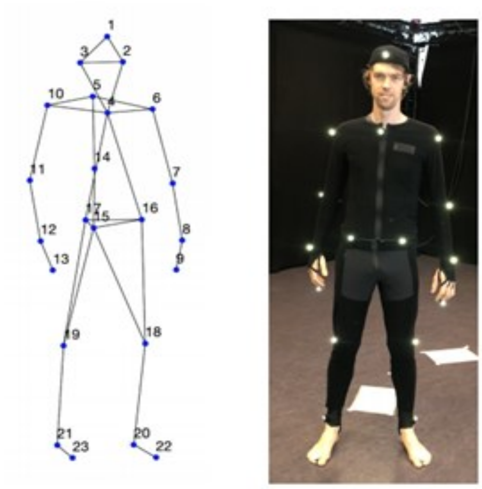


Figure 4. Visual representation of the design of reflective markers.
Source: Own work.

3.2. The recording sessions

After fitting on a full-body motion-capture suit and receiving a brief introduction to the objectives of the research project, each participant underwent a short training session to learn the choreography for the Macarena. While not an Indigenous dance, the Macarena was chosen due to its simplicity and the fact that all members of the research team were already familiar with it. As such, the Macarena in this experiment is used for illustrative purposes and to reach preliminary conclusions on how the resulting similarity metrics might be made available for the protection of Indigenous dances in future applications. This briefing was also intended to familiarize participants with the experience of dancing in a laboratory setting with thirteen infrared cameras pointed at them. This particular setting could be intimidating for some participants, especially considering that most did not have any previous training in dance or the performing arts more generally. In order to make participants feel more comfortable, it was decided that a member of the research team would always be present to dance together with the participants during the recording process. For the first four recordings, each participant was told to "just do the Macarena dance" without any further specifications. However, for the following three takes, the participants were requested to do the minimal amount of movements required "to perform the Macarena and nothing more". For the final three recordings, participants were encouraged to dance the same sequence "as if they were really enjoying it". These verbal instructions were included in a written protocol used to standardize the recording sessions for this specific study. The three levels of expressivity across the recordings were delimited within the research team as, "normal", "deadpan" and "exaggerated" as a way of triggering participants to move in different ways while keeping the same choreography[7].

Figure 5. Still of the motion-capture laboratory employed for the experiment. Source: Own work.

The recording sessions were followed by a post-processing phase, in which all of the resulting files underwent rigorous treatment to label the unidentified trajectories of the markers within the Qualisys system. Additionally, the Trajectory Editor tool was employed on each recording to fill the gaps between not only the unlabeled markers but also the non-measured ones, or those gaps generated when the infrared cameras stopped recording for an instant because of overlapping parts of the body. The exception to this is the several cases where, as a result of the gaps being filled, a deformity appeared on the body that altered its natural constitution. After completing, cleaning, and reviewing the trajectories of the markers to ensure they were satisfactory on each individual file, they were entered as suitable material to be used later for the calculation of similarity.

A decisive point within the execution of this project was the discussion on how to delimit the content of the dance itself and what should be considered as part of its stylistic variations. While this conversation was informed by theoretical considerations, for the purpose of the experiment it needed to be translated into measurable, deployable algorithms. Prior to using the computer-based system to produce a similarity report based on the recorded material, the interdisciplinary team of researchers needed to first clarify its metrics for calculating similarity.

[7] These three levels of expressivity follow a common system of categorization in the field of human movement recognition. For a compilation of precedent studies, see Thompson, M. et al.: "Starting with Davidson's seminal 1993 study, a popular design has been to instruct musicians to perform with varying expressive manners […] ––manners might include: deadpan (i.e., without expression), projected (i.e., with normal levels of expression), and exaggerated (i.e., with exaggerated levels of expression" (Thompson, 2017, p. 5).

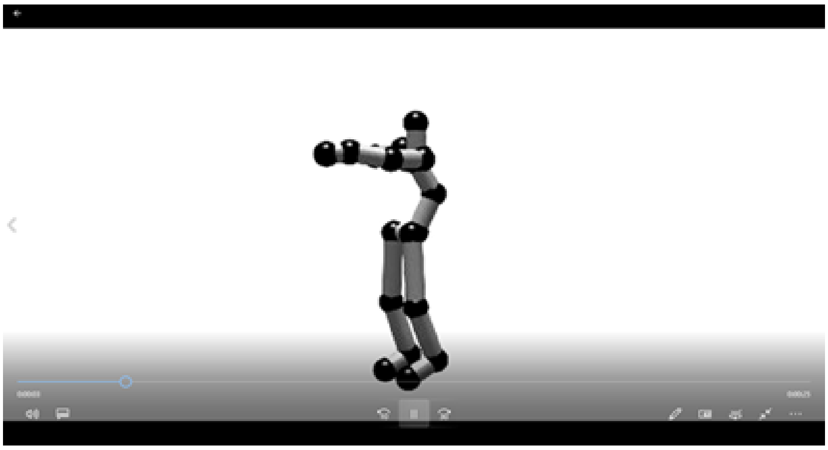


Figure 6. Computer-generated 3D animation extrapolated from the recording sessions. Source: Own work.

3.3. Running the similarity report

The first part of the similarity report was designed to measure the similarity of content or the steps of the dance recorded in themselves. Two general approaches to assess this aspect were implemented. First, the Euclidean distance between the marker trajectories of each performance was measured. To ensure the distance scores were invariant to the spatial location of the participant, the data was first normalized in reference to each recording's root marker (labeled as marker 17 in Figure 4). An additional similarity metric was implemented to examine the sequences drawn from joint angles. The consideration of joint angles rather than marker positions was useful in order for the measurements to be invariant to the spatial positions, as well as size variations, of the performer. This first half of the similarity report intends to express whether or not performers across recordings are executing the same steps.

As previously mentioned, the second component in assessing the level of similarity between dances involved the way in which the steps are performed or the stylistic traits of the dance. Laban's theory (Laban and Ullmann, 1988) was utilized to establish a set of dyadic parameters that could guide the task of evaluating the performances in terms of style. To distinguish if a movement within a recording was either sustained or sudden, the amount of acceleration over time was measured. When it came to calculating whether movements were direct or flexible, the cumulative distance traveled by select markers placed on the bodies was observed. If a step was to be categorized as gentle or firm, velocity was used as a determining factor. Finally, to quantitatively describe the quality of movement, such as how abrupt (jerking) or smooth (flowing) it was, the derivative of acceleration was estimated. In summary, all of these parameters were intended to account for the stylistic traits included in each of the recorded performances.

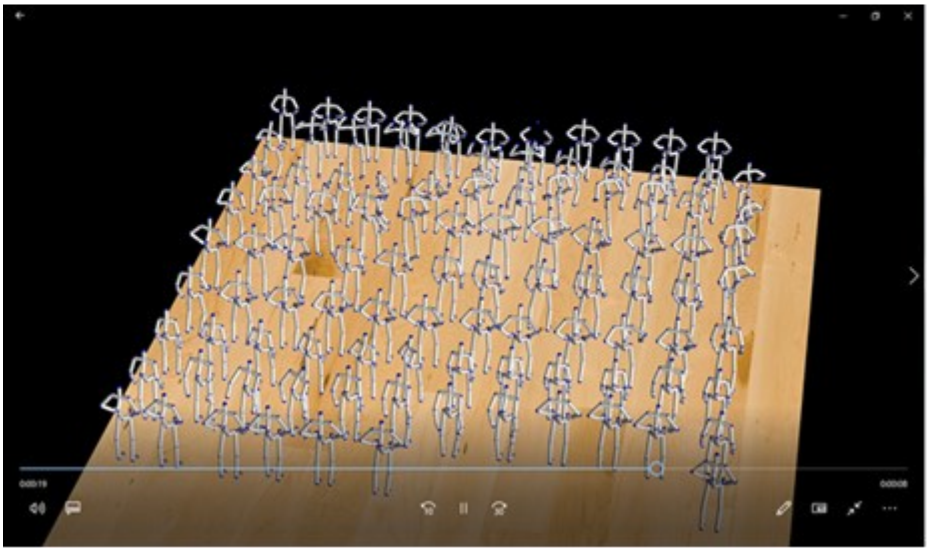


Figure 7. Computer-generated 3D animation comparing different recordings of the same dance. Source: Own work.

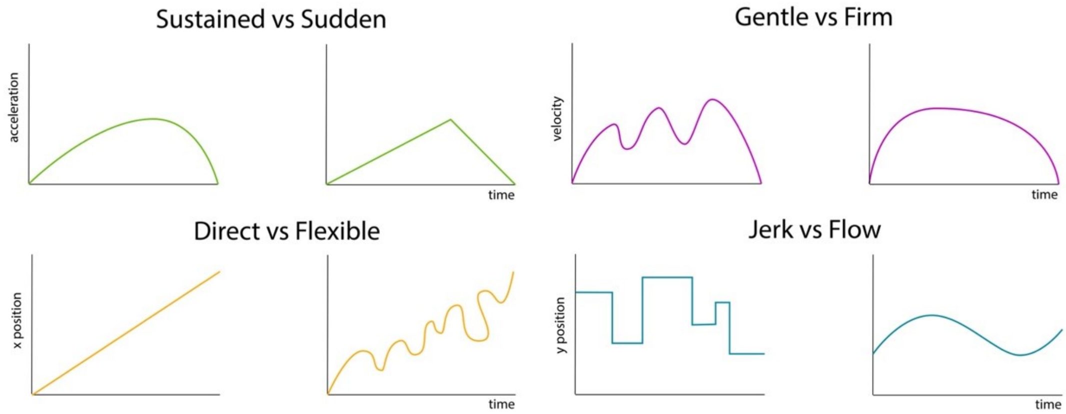


Figure 8. Visual representations of the stylistic traits of recorded performances, including the amount of acceleration over time (sustained vs. sudden), the cumulative distance traveled by select markers (direct vs. flexible), the velocity (gentle vs. firm), and the derivative of acceleration (jerk vs. flow). Source: Own work.

Once this two-fold design was established, the previously recorded data needed to be recovered. The material employed to test the suggested movement similarity system was the collection of recordings portraying the same dance over three hundred times (one hundred recordings each comprising three repetitions).

The ability to recognize specific gestures is useful in human-computer interaction, human-robot interaction, and information retrieval tasks. When recognizing certain motion sequences, it is advantageous for a system to remain invariant to the way a movement is performed as the personal characteristics of users may differ greatly in their temporal, spatial, and stylistic idiosyncrasies. After a target gesture is identified, one approach to ensuring invariance is to create a robust movement template by which various examples of dance can be compared. Although motion templates have the potential to accurately measure recordings of well-defined dances such as the Macarena, in which participants are all performing the same choreography, this approach is not necessarily as useful for comparing examples of different forms of dance. Moreover, creating templates for each possible pose or movement sequence in the world of dance would be an extensive, if not insurmountable, undertaking. As an alternative, two other general approaches were implemented. Firstly, the Euclidean distance between the marker trajectories of each performance was measured. To ensure the distance scores are invariant to the spatial location of the participant, the data was first normalized in reference to each recording's respective root marker, thereby creating a local coordinate system fixed within the body. The second similarity metric used involved measuring the differences between sequences of joint angles from several body segments. When using joint angles instead of marker positions in a local or global coordinate system, the results are invariant to both the spatial position of the body and the variation in limb length. By treating the angle between different segments at each frame as a sequence, the recordings could then be compared using dynamic time warping, resulting in a collection of pairwise dissimilarity scores. Dynamic time warping (DTW) is a common approach to time series comparison used in various signal processing tasks. Although the two sequences may be different with regards to their Euclidean distance, they may still share an overall shape that does not necessarily line up in relation to timing. By stretching or compressing one or both time series, the DTW algorithm finds the minimum distances between each point in the two sequences. The sum of these minimum distances produces a score that is interpreted as the amount of dissimilarity. Identical time series will have a DTW score of zero. Although the aforementioned methods facilitate the clustering of similar examples without pre-existing knowledge of what motions the examples contain, using DTW can be a slow and computationally heavy operation, and, as a result, these methods are often too costly to be implemented in certain systems.

What follows is an example of how the selected similarity algorithm evaluated the degree of similarity between two performances based solely on the head marker (as seen in Figure 4).

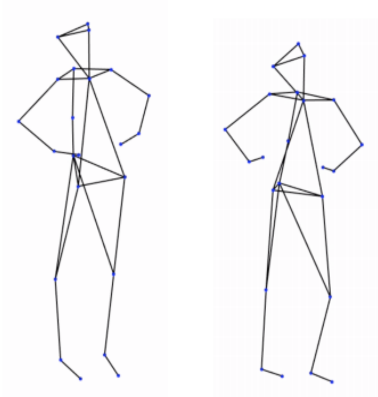


Figure 9. Recording “a” and “b” by subject 2.
Source: Own work.

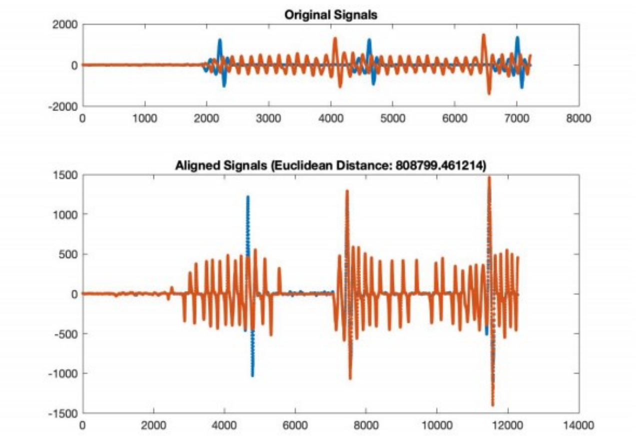


Figure 10. Visual representation of the similarity between “a” and “b”, represented in different colors[8]. Source: Own work.

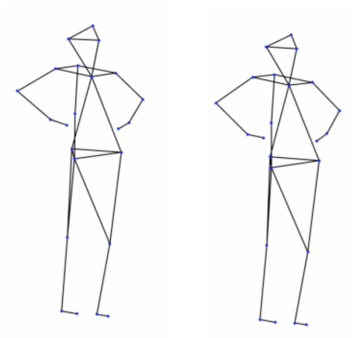


Figure 11. Recording “c” and “d” by subject 4. Source: Own work.

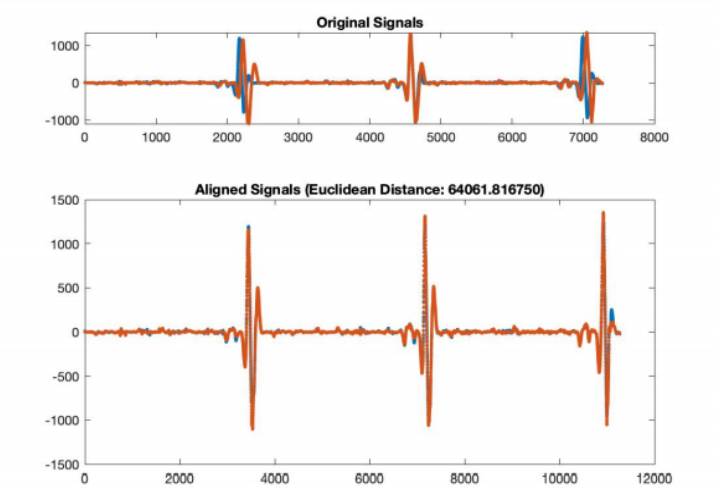


Figure 12. Visual representation of the similarity between “c” and “d”, represented in different colors. The Euclidean distance (~64,061) is of a noticeably smaller value when compared to that of Figure 10. Source: Own work.

[8] The original signals show the change in x, y, or z position of the two markers over time. The aligned signals show the numeric value of the difference between the two signals (the Euclidean distance), which is also referred to as the DTW, or distance between signals using dynamic time warping. The more similar the two signals are, the lower the value their Euclidean distance will be (e.g. two identical signals would have a value of zero). This figure, which compares two takes from the same subject, is provided as a visual aid of the DTW function. In the experiment, the DTW function was used to calculate the differences between every example and place them in dendrograms based on their degree of similarity.

As seen in Appendices A through F, when running the Movement Similarity Project under the parameters described, the recordings were clustered in ways that coincided with the similarity perceivable under visual inspection, which was initially encouraging. For example, a comparison of the degree of similarity between two recordings showed that they had similar jerk curves that corresponded to how we perceived them as similar through visual inspection. However, the value of these calculations is precisely that they extend beyond immediate observation and offer a quantitative insight into their actual degree of similarity. The conditions (i.e. enthusiastic, deadpan, and normal) were not separated beforehand in order to evaluate whether or not the metrics would reveal clusters that corresponded to them, and the results were partially successful in how they showed that for some metrics the degree of dissimilarity was higher between conditions than it was between subjects, while other metrics showed the opposite. The Movement Similarity Project is intended as a complementary tool that could work alongside the irreplaceable knowledge of skilled experts trained within particular dance traditions. It intends to strengthen and support claims of the misappropriation of Indigenous dances through computerized reports. Such complementarity is relevant since decision-makers often lack knowledge about dance or movement, which is why it is common practice for them to consult external experts for assistance in determining the validity of claims made in courts.

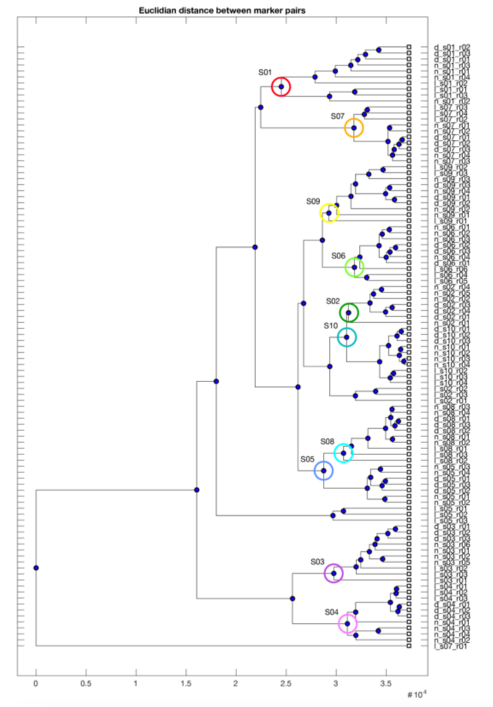
4. PRELIMINARY CONCLUSIONS

No general system appears to be able to assess the level of resemblance across different dances unless more advanced techniques such as machine learning are incorporated. While the proposed system was partially successful in clustering the examples in a way that is consistent with our visual inspection of the recordings, these results are predicated on the simplicity of the dance used for this experiment, meaning that it would not be possible to use these metrics if the dancers were not for example, following the same choreography to the same beat. While this experiment yielded partially successful results given that a similarity metric was developed and proven to provide accurate assessments in a limited set of conditions, future applications of such a method for the safeguarding of Indigenous dances will require further innovations to account for the variability of dance practices and human movement. These additional innovations, whether they involve machine learning or other new technologies, may also not function as practical tools given how many Indigenous populations are negatively impacted by the digital divide. Throughout the process of this experiment, the researchers made decisions to adjust the accuracy of the similarity calculations based on previous knowledge of the dance used in the recordings. This is to say that intrinsically, similarity reports cannot serve as standalone assessments but rather must complement the qualitative information of non-computer-based metrics, such as the perspectives of dancers within the tradition under inspection. Additionally, further extrapolations are needed to adapt the outcomes and possibilities of this project to make it accessible to Indigenous communities that may need it to sustain claims of misappropriation.

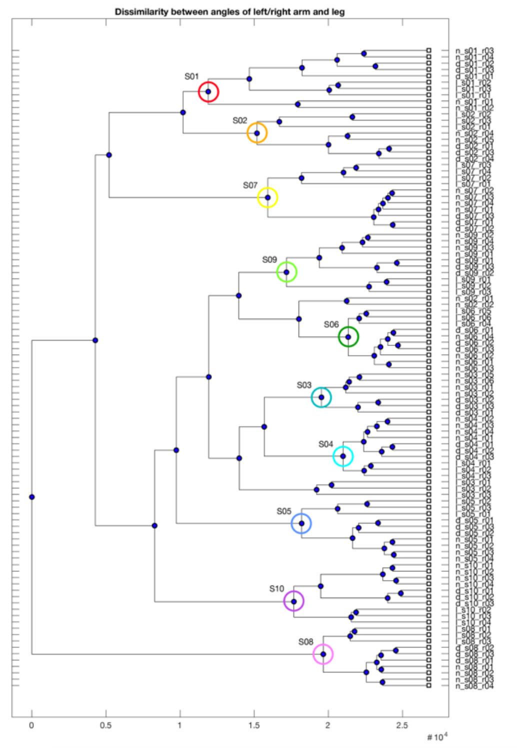
The set of metrics employed in the Movement Similarity Project resulted in a new organization of the recordings based on their degree of similarity. A sample of the comparison between two individual recordings can be seen in the previous section. However, in Appendices A through E, the entire pool of recordings was compared simultaneously, resulting in clusters that are plotted according to the mode in which they were performed ("1" for enthusiastic; "d" for deadpan; and "n" for normal), the identification of the subject being recorded (from s01 to s10), and the iteration (r01 to r04; three iterations each for enthusiastic and deadpan, and four iterations for normal). As such, iterations that scored closest to each other were combined in pairs, and the branches along the x-axis display the group's average distance in relation to the rest of the pairs. By following the branches of these dendrograms, the distance between one example and the rest reveals the degree of similarity measured according to the parameters explained in the previous section.

While there is some evidence to support the hypothesis that technological resources could assist in the assessment of cases of misappropriation of Indigenous dances by quantitatively reporting a degree of similarity, there is still work to do in terms of contrasting the results of the computer-based system with human perception. This will shed light on the type of metrics required to accurately portray the degree of similarity both in terms of the steps and styles of each dance.

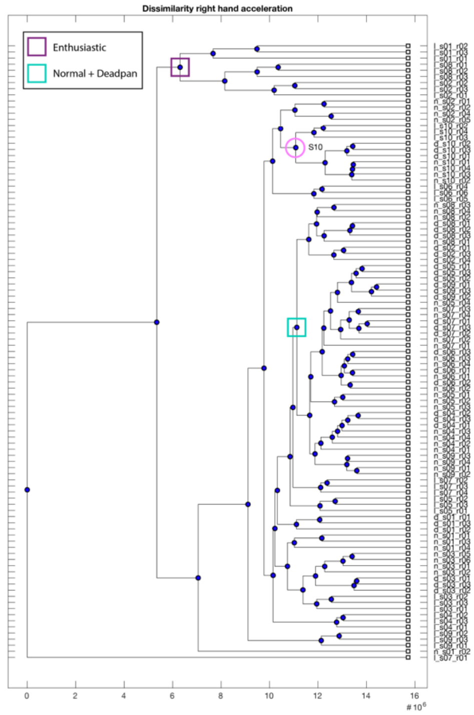
Finally, it should be mentioned that similar patterns of movement might be found across different Indigenous dances that are unrelated or belong to territories far from each other, as similarities may stem from the obvious use of the human body. In these situations, for example, a case in which two different Indigenous communities might have competing claims surrounding the ownership of a tradition, it would be difficult to find ways to establish authorship or originality based exclusively on movement analysis. For this reason, a multi-modal approach to dance is required to consider including its multiple visual, kinetic, cultural, and symbolic aspects. A case of misappropriation of Indigenous dances could therefore be assessed through an approach that utilizes movement analysis but does not reduce it to the idea that *the same steps equate to the same dance*. A further phase of this investigation would suggest utilizing the possibilities discovered through these technological tools to analyze human movement and match it to shortcomings or gaps that Indigenous communities have identified in efforts to safeguard their expressive cultures.



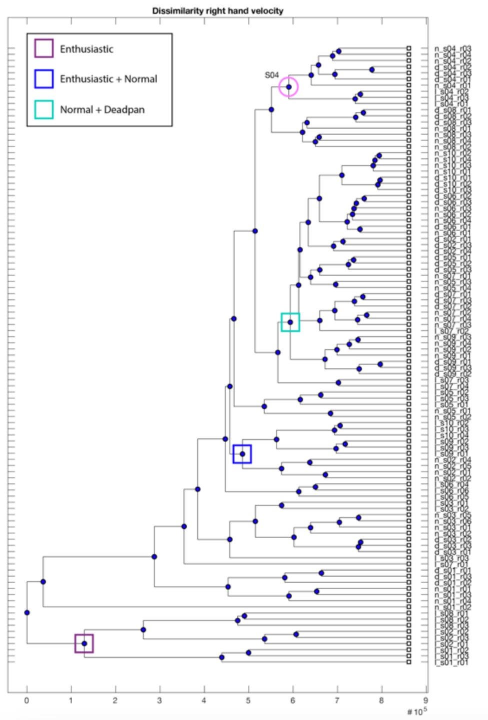
Appendix A. Euclidean distance between all markers.
Source: Own work.



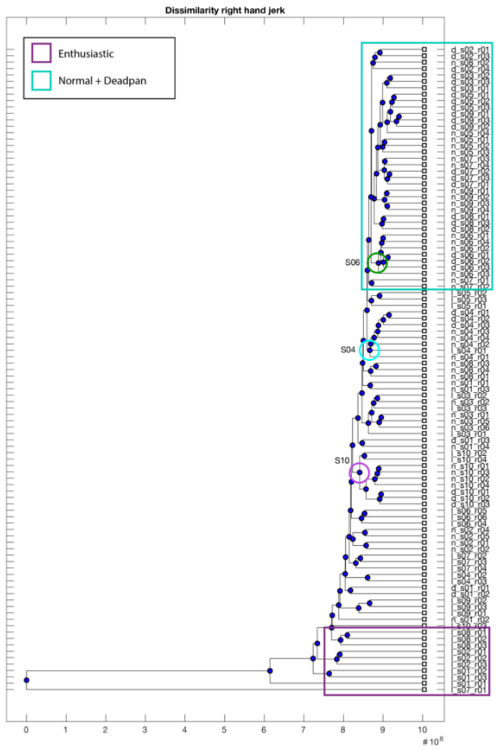
Appendix B. Dissimilarity between angles of left and right arm and leg across all examples. Source: Own work.



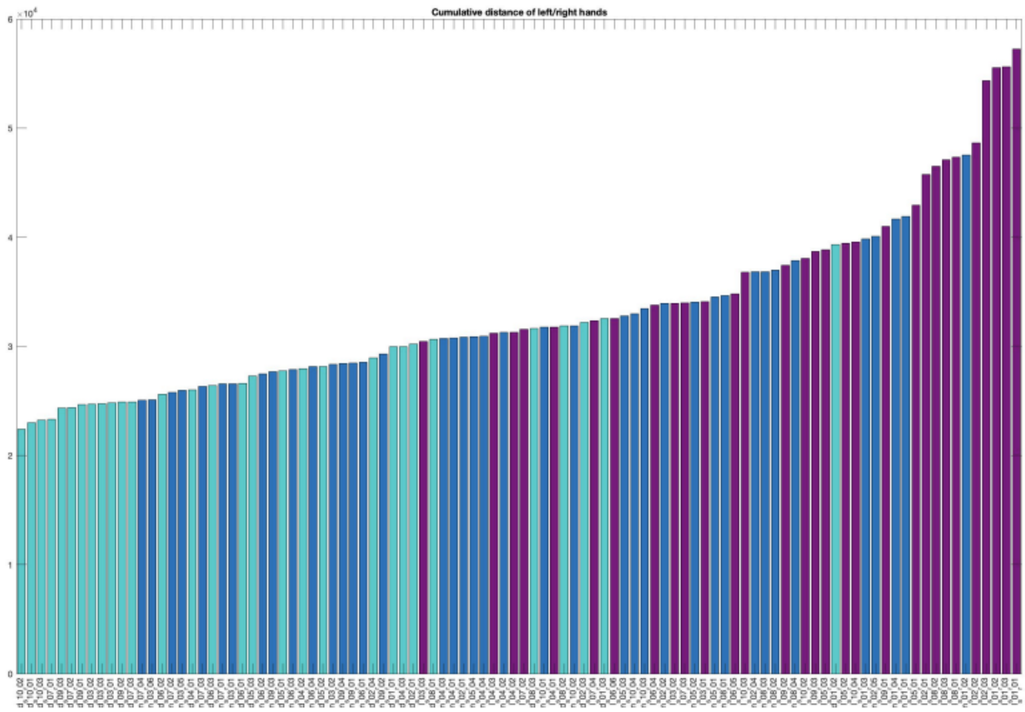
Appendix C. Dissimilarity in relation to sustained or sudden qualities, measured by the acceleration of the right-hand marker. Source: Own work.



Appendix D. Dissimilarity in relation to gentle or firm qualities, measured by the velocity of the right-hand marker. Source: Own work.



Appendix E. Dissimilarity in relation to jerk of flow qualities, measured by the jerk of the right-hand marker. Source: Own work.



Appendix F. Cumulative distance traveled by right-hand markers (results shown in mm). Light blue = deadpan; dark blue = normal; purple = enthusiastic. Source: Own work.

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