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# The Notion of Dialogue in the Interactive Dance

## with the focus on Hip-Hop dance

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## Abstract

The constituent elements of interactive dance are human and computer, which in human-computer interaction, create a feedback loop, and present the work of art. Considering that matter, each of the opponents in this common interaction has their part and space and there is an aesthetic relationship ongoing, defining the amount of each opponent's part and space. In this thesis, this ongoing matter is referred to as the notion of dialogue. To create this sense, the key element that will be discussed is surprise. After that, following a certain design strategy, a practical system will be designed and executed to fortitude the logical argument that is presented in this research. In that performance, by the creative use of the body, space, time, popular art forms (i.e., Hip-Hop music and dance), and with the focus on the subject of sea-level rise, the research argument will be put in practice and further on evaluated. After the evaluation process, considering its limitations, it may be concluded that the use of surprise, will allow the computer to have an active role and possess a significant part in the interaction, in order to convey a sense of dialogue in it.

# Acknowledgment

I would like to express my sincere gratitude to my supervisor, Associate Professor Andreas Bergland for the continuous support of my research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me a lot during the research and writing of this thesis, and I have learned a lot from him during this procedure, which I am very grateful for that.

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# Preface

As it was mentioned in the abstract, a practical work is included in this thesis. This practical work is done, to implement theoretical arguments proposed in the thesis. Obviously, the evaluation of practical work has an important role in the assessment of the theoretical argument. To do that, it needs to be examined and used by several users. The feedback from the users needs to be gathered and analyzed, to reach a suitable conclusion.

However, due to the Coronavirus pandemic[1] and the Norwegian University of Science and Technology's restrictions (NTNU, 2020) regarding that, and also the limited timeframe for the submission of the thesis, it was not possible to have access to the dancers. Therefore, I had to turn into another alternative, as it is going to be mentioned in the respected section - Evaluation of the practical work.

Also, the milestones and schedule of the iteration in the design process were interrupted by this situation as well, since the original planning was to perform the iterative design in collaboration with a dancer/co-designer, but I had to perform the iteration process after getting feedback from the user.

[1] The new coronavirus (Covid-19) pandemic that has spread to nearly every country in the world since it first emerged in China at the beginning of 2020 (The Telegraph, 2020).

# Blog page

There is a blog post available for this thesis, which integrates the accompanying material such as video and audio. Following the URL of this blog post can be found:

https://mct-master.github.io/masters/2020/06/10/SHthesis.html

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| | |
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| NTNU | The Norwegian University of Science and Technology |
| IMU | Inertial Measurement Unit |
| UDP | User Datagram Protocol |

# 1 Introduction, Background, and Main objective

Just as other art forms, dance has been significantly influenced by the development of digital technology over the last three decades (Mullis, 2013). Electronic or digital interactive systems have been experimented within the dance domain (Bevilacqua, et al., 2011). ‘Full-body interaction with electronic or digital media has undergone experimentation for more than fifty years both in arts and science communities’ (Alaoui, et al., 2013, p. 358). There have been different analyses regarding the nature of this interaction, exploring it from different perspectives. The ones that are in the area of interest here, are those arguing the bidirectionality, feedback loop, and design in the interactive dance. These notions are widely discussed in previous research, such as ‘Identifying a dynamic interaction model: A view from the designer-user interactions’ (Park & Boland Jr., 2011), ‘Dance and Interactivity’ (Birringer, 2004), ‘Dance, Interactive Technology, and the Device Paradigm’ (Mullis, 2013), and so on.

As a sound artist/engineer, I have previously participated in the creation of an interactive dance performance that involved a dancer and two sound artists/engineers, interacting with each other through a feedback loop. The dancer was the initiator of the performance and the sounds created by her movements were received by the sound artists. They manipulated the sounds and played them back to the dancer, which provided her the sonic material to dance to. In this interaction, the interesting point was that the dancer found it hard to define her active role/part in this interaction. In other words, it was challenging for her to recognize if she had more influence on the sound artists - by the creation of the sounds - or she was more under the influence of the sound artists. This presents the effort of each opponent in the interaction, to possess their part in this interaction. This effort is dynamic and the possession of one’s part in the interaction may differ in each moment of the interaction. Thus, I became interested in analyzing the interaction between the participants in the interactive dance, and their effort in taking their parts in the interaction. However, this time in the context of the interaction between the dancer (i.e., a human) and a computer. Further, the research question will be mentioned and to elaborate and clarify the thesis question, a preliminary introduction to the concepts and terminologies used in the question, and the thesis will be provided.

The research question in this thesis is: ‘How and to what degree can an interactive dance performance with a Hip-Hop dancer using absolute orientation sensors and auditory input, convey a human-computer interactive dialogue through surprise and movement-sound mappings?’

In the first step, to describe the characteristics of the participants in the interaction and the interaction itself, Mullis’s argument regarding *bidirectionality* and his overview of Borgmann’s theory will be utilized. According to Mullis, bidirectionality is derived from ‘a causal relationship between movement and environmental output is made possible by an interactive platform that functions as a continuous biofeedback system’ (Mullis, 2013, p. 112). Based on Borgmann’s perspective, he discusses that ‘modern technological *devices* are technological instruments that function in a particular manner that distinguishes them from earlier forms of technological instruments' (Ibid., p. 116). He mentions that:

> early technological hardware was generally large and bulky, to the extent that one could readily see how internal mechanisms functioned…This is distinct from modern technological devices that…are increasingly so compact that their inner workings are not visible to the naked eye (Ibid., p. 116).

Inspired by that argument, the non-human part of the interactive dance system will be referred to as *the device*, which includes the computing system and its input and output organs (e.g., sensors, microphones, speakers, projectors, and so on). Put differently, the interactive dance system consists of the interaction between the dancer and the device, which can be observed in figure 1.1:

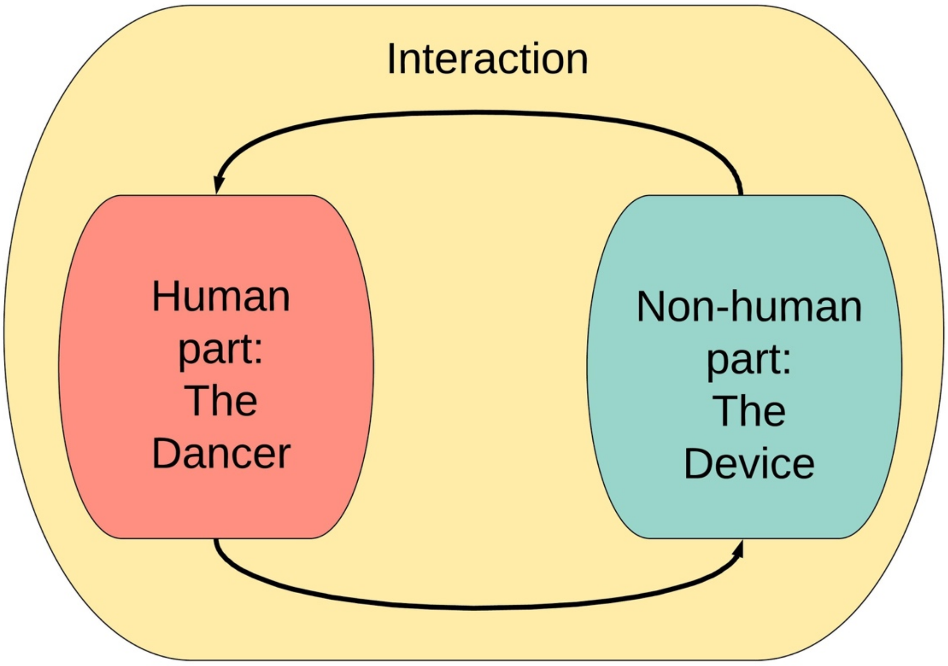


*Figure 1.1: Interactive dance system*

Since the participants in the interaction are the dancer and the device, it requires the device, as the non-human part of the interaction, to take certain measures to be able to convey a sense of an active opponent for the dancer. That means in this common interaction, the device may become able to possess its part in the interaction, in a dynamic manner.

To elaborate more on the matter of possessing parts in the interaction, the notion of *aesthetics* is a key concept. Here, Jacques Rancière's definition of aesthetics will be utilized. He refers to the aesthetics as the system of a priori forms, determining what presents itself to sense experience (Rancière, 2004). In the interactive dance, the device and dancer are the participants and possess their part in the interaction. In this thesis, this ongoing struggle is referred to as the notion of *dialogue*. The measure proposed for the device, in the design process, to allow it to play an active role and convey a sense of dialogue, is *surprise*. This endeavor will be made, utilizing the strategies that the researcher will provide, including *randomness* and *mapping techniques*.

Further on, to fortitude the theoretical argument, based on it, a system, suitable for Hip-Hop dance will be designed via collaboration with a Hip-Hop dancer, then presented and evaluated. In the design procedure, certain strategies and models will be addressed. Those include of Park and Boland's proposed interaction models[2] (Park & Boland Jr., 2011) and Bevilacqua, Schnell, and Alaoui's work on the classification of the different approaches for sensing gesture as used in dance performance, using three main categories, *body*, *space*, and *tim*e (Bevilacqua, et al., 2011).

The reason for choosing Hip-Hop dance was the availability of a Hip-Hop dancer at the time of doing the research. However, after getting more engaged with the research, the possibility of presenting a new sensory experience, regarding popular art forms (e.g., Hip-Hop art), became an interesting matter to be addressed, in possible future works.

Regarding the subject of the practical work, according to Robinson, it can be stated that dance as 'a multidisciplinary and multicultural practice has embodied history, ethnicity, gender, biology, and visual and performing arts, as well as technology and computer sciences' (Robinson, 2016, p. 780). Thus, various subjects may be presented and expressed via dance, in a performance. Here, the subject chosen for practical work is the matter of sea-level rise. There is a certain study regarding the matter of sea-level rise and the way that it harms people, especially in the coastal regions, by Nobuo Mimura (Mimura, 2013). Those harms include exacerbated inundation and flooding of low- lying coastal areas, increased coastal erosion, effects on coastal ecosystems, saltwater intrusion into estuaries and, aquifers, and so on (Ibid.). Although, since this issue has recently come into the area of the attention, there are not that many artworks, derived by it. However, some artworks point out that matter, which fall into other categories. For instance, an installation by two artists from Finland, Pekka Niittyvirta and Timo Aho, by the name of *Lines (57° 59΄N, 7° 16΄W)*. It is an outdoor installation in coastal Lochmaddy, Scotland, 'that uses sensors to detect high tide, which then activates three synchronized light lines illuminating the projected high tide of the future if climate change progresses at its current pace.' (Sharp, 2019)

According to Latulipe and colleagues, 'the production process in dance can be understood as a generative dialogue between the varying 'actors' of movement' (Latulipe, et al., 2011, p. 107) including sound, lighting, props, costuming, scenic elements, and digital effects. In this system, the actors are visuals and sounds. Here, the area of attention is on the most common interaction between the dancer and the device in the electronic arts, which is the interaction between the performer and the system (Bongers, 2000). In regards to the device, two interaction modalities, or communication channels, are being used; the visual input modality (i.e., projection) and the auditory input (i.e., sounds) (Ibid.). The dancer is communicating with the device on a somatic level and also via auditory input.

Going back to the theoretical argumentation, the aim of the practical work in this thesis is not necessarily to point out the issues revolving the subject of the interactive system (e.g., to present an impression of harm to mankind to the audience), but to discuss the sense of dialogue in the interactive experience between the performer/dancer - in this case, a Hip-Hop

[2] Interaction of Designers, Interaction of Users, and Mutual Interaction Between Designers and Users (Park & Boland Jr., 2011).

dancer - and the device. In this procedure, the focus is on the perspective of the user/dancer and the way the device's behavior affect it, in an interactive system.

Moving on to the next sections, to answer the research question, firstly in the theoretical framework section, theoretical concepts that provide a suitable platform for the research to analyze the characteristics of the participants in the interaction, and also the interaction between them will be discussed. Then, based on those an argument will be presented to address the main concerns in the research, and a logical deduction will be presented. Finally, a system shall be designed, utilizing the presented argument, and will be put into practice for its evaluation.

## 2 Theoretical framework

Regarding the notion of interactivity, Birringer looks at it in the narrower sense of collaborative performance with a control system in which the performer's movement is tracked by sensors and used as input to activate or control other component properties from media such as video, audio, text, graphics, and so forth (Birringer, 2004). In continuation of the that, interactive dance performance designates performances in which a dancer's movements, gestures, and actions are read by sensory devices, translated into digital information, processed by a computer program, and rendered into the output that shapes the performance environment in real-time (Mullis, 2013). In this thesis, the research objective is rooted in an interactive dance system that allows the dancer to generate, synthesize, and process videos and sounds within a shared real-time environment.

In the first step, elaborating more on the notion of bidirectionality, as if was aforementioned, Mullis refers to it as a causal relationship between movement and environmental output is made possible by an interactive platform that functions as a continuous biofeedback system. This process allows performers to experience bidirectionality since they are aware of their ability to modify the environment and are aware that interactive technology can affect their actions (Ibid.). Mullis refers to this, 'as an interesting tension that develops in which the two ontologically distinct creative forces contribute to the work' (Ibid., p. 118). Here the aim is to build the concept of dialogue, on a quality of bidirectionality that is based on both participants (i.e., the dancer and the device), taking their parts in the interaction and acting towards each other, not for instance, a device that is only reacting towards the performer's action. Hence, it is important to consider the point that in the relationship between the performer and device, how the affordances of the system will affect the dancer's movements.

Consequently, we have a device on one side of the interaction, and the other side a dancer who is interacting with it. These entities, act and react towards each other via their inputs and outputs - sensors and actuators in regards to the device and senses and effectors in regards to the dancer - and maintain a bidirectional relationship. According to Bongers, sensors are the sense organs of a machine and its output takes place through actuators. In the case of humans, the inputs are senses and the outputs are referred to as effectors (Bongers, 2000). This procedure can be observed in figure 2.1:

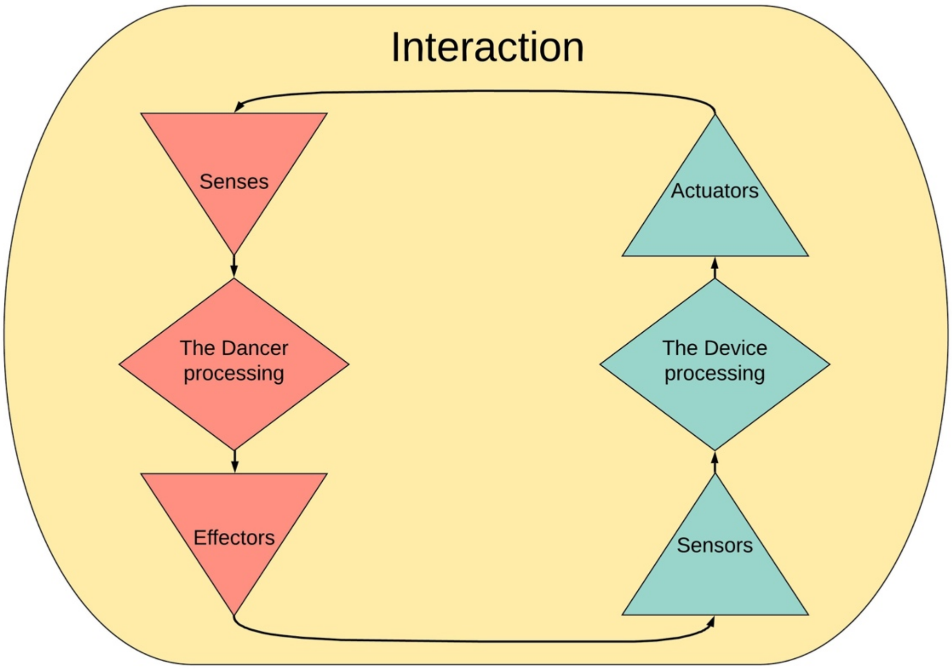


*Figure 2.1: The dancer and the device interaction*

Elaborating more on the concept of bidirectionality from Mullis's perspective, there is an issue he raises in his argument. He mentions that the projected code (i.e., the device) responds to the dancer's input via actuators - audio/visual outputs. According to him, the dancer needs to interpret his/her behavior and relate his/her movements to the device's behavior. But he finds this an obstacle in experiencing the bidirectionality. As he says 'the effort required to interpret computer computation would interfere with a phenomenological sense of intertwining since the dancer would be engaged in a demanding cognitive process' (Mullis, 2013, p. 121).

Although he does not disregard 'the experience of the dancers who have first-hand experiences of interactivity, since, all things being equal, one cannot discount the veracity of another's phenomenological experience' (Ibid., p. 121). But I do not find this argument convincing to address the raised issue and will address it from a different perspective.

In the domain of interactive dance, this cognitive process is an inherent matter. Reybrouck in his article about *musical sense-making* mentions that in such context:

> cognition cannot be reduced to a detached and disembodied nature of it (Schiavio, et al., 2016) On the contrary, it calls for an embodied and enactive approach that conceives of music users as organisms that are endowed with a sensory and motor apparatus that enables them to carry out interactions with their environment (Reybrouck, 2017, p. 79).

To be more elaborate on the concept of musical sense-making, it 'involves a process of "semiotisation" of the sonic world and can be subsumed under the field of *ecosemiotics* (Kull, 1998) which studies the semiotic interrelationships between an organism and its environment' (Reybrouck, 2012, p. 393).

Here, the semiotic relationship is ecologically constrained and in function, is the driving motive for addressing matters. In this case, it refers to the organism - music user - picking up relevant information - music - from its environment. Therefore, in this interaction, on a sensory level, the cognitive process is innate since the user is picking up the relevant information in the aforementioned semiotic relationship and use it in the interaction. Also, in this case, an enhanced sense of mutuality between the device's end and the dancer's specialization, fortitudes the sensory experience in their interaction. Therefore, this cognitive process cannot be counted as an obstacle in the interaction, but an innate matter in it.

After elaborating on the concept of bidirectionality, further on, the notion of the dialogue and strategies to reach to that sense, via device's behavior, will be mentioned. However, to do that, a brief preliminary reminder may be beneficial. Developing based on the notion of bidirectionality, the focus here is on moving towards a quality of bidirectionality that is based on both sides acting towards each other, not for instance a device that is only reacting towards the performer's action. Thus, it is important to consider that in the relationship between the performer and the device, how the affordances of the system will affect the dancer's movements.

## 2.1 Dialogue

After providing the necessary theoretical basis, I now elaborate more on the definition of dialogue, as a key term in the research question. Here, dialogue refers to the amount of participation of the dancer and the device, in the causal relationship between them, in the system. It is a matter that needs to be addressed, considering the aesthetical relationship in the interactive dance, which can be referred to as the experience of correlationship, correspondence, or causality between the input - the dancer's senses and device's sensors - and the output - the dancer's effectors and device's actuators. Despite Mullis's term, "bidirectionality", there are several other ones that conceptually are close to this in the writings about interactive dance as well: Wilson and Bromwich use the term "awareness", and Rizzo and colleagues refer to it as "feedback" (Rizzo, et al., 2018).

To describe the notion of dialogue more precisely, it is necessary to elaborate more on the definition of aesthetics. From Rancière's perspective, 'aesthetics can be understood in a Kantian sense - re-examined perhaps by Foucault - as the system of a priori forms, determining what presents itself to sense experience' (Rancière, 2004, p. 13).

In his perspective, a distribution of the sensible establishes something common that includes exclusive, shared parts:

> this apportionment of parts and positions is based on a distribution of spaces, times, and forms of activity that determines the very manner in which something in common lends itself to participation and in what way various individuals have a part in this distribution (Ibid., p. 12).

Regarding interactive dance, aesthetics refers to the dynamic share of each participant, in the apportionment of parts and positions in the interaction. By dynamic, I am referring to the amount of this participation, not being static and changing on a temporal level in the process of interaction. These possessions of parts, consequently are the constituent elements of the interaction between the device and the dancer. The effort of taking parts and possessing them in a common thing - in here, the interaction - can be referred to as dialogue. In other words, it is an ongoing collision of forces of the participants that are working together at the same time, and each demands their place in the interaction.

There are forms of interactive dance in which the dancers are using their body as an instrument to control the performance/installation, or as Qian and the colleagues mention, they are in 'full control of the background music and visual display through their movements' (Qian, et al., 2004, p. 1). Put differently, the dancer is possessing all the parts in the interaction. In this manner, the device only reacts to the dancer's movement. Therefore, the device should be empowered to possess its part in the interaction as well as the dancer, by reducing his/her control and possession of parts in the interaction. Regarding that matter, the device should act.

Here, it is important to address *action* and *reactions* in the device's behavior. There are parts in the device's behavior that are independent of the dancer's input. For instance, certain sounds or videos or behaviors that are not responsive to the dancer's input. Those are referred to as actions. But there are also parts of the device's behavior that are responsive to the dancer's movements and change, due to the input. Those parts are referred to as reactions. Although getting more into the details, the device may imply independent manipulations on its reactions towards to dancer. That simply means the response of the device to a certain movement may vary, based on various factors, each time that movement is being executed. Those types of reactions can be referred to as *dynamic reactions*, in contradiction to usual reactions, which are always the same regarding the input data (i.e., the dancer's movements). Overall, it can be stated that the device's actions, reactions, and dynamic reactions will be perceived by the dancer and will affect his/her cognition process and perception of the device's behavior and eventually his/her part in the interaction.

However, predictable and iterative behavior will be learned by the dancer and will eventually lead to his/her full control over the device. Therefore, the proposed idea here is to utilize the notion of *surprise*, to allow the device to counteract the aforementioned issue and maintain the possession of its part in the interaction. In this case, the use of surprise shall lead the performer to not to have the full control of the interaction. This surprise is going to happen, through two main strategies: *dependent mapping technic* and *randomness*. These strategies shall be implemented in the actions and dynamic reactions of the device and have a key role in allowing the device to maintain the possession of its part in the interaction. Further on, after elaborating more on the concept of surprise and the way it can affect the interaction, the aforementioned strategies will be explained more in detail.

## 2.2 Surprise

To elaborate more on the concept of surprise and the way it can be utilized to create a sense of dialogue, I may refer to David Huron's arguments in his book *Sweet Anticipation: Music and the Psychology of Expectation* (Huron, 2006). Although his book deals with how expectation plays a part in music, his arguments should also have some relevance for interactive dance. Also, several steps and concepts need to be discussed for that purpose, starting with *expectation*. Regarding the music, expectation is an important subject in the listener's experience. According to Huron, 'the story of expectation is intertwined with both biology and culture. Expectation is a biological adaptation with specialized physiological structures and a long evolutionary pedigree' (Ibid., p. 3). Although Meyer has argued that 'the principal emotional content of music arises through the composer's choreographing of expectation' (Ibid., p. 2), but on a more comprehensive scale, Huron argues that 'minds are "wired" for expectation. Neuroscientists have identified several brain structures that appear to be essential for prediction and anticipation' (Ibid., p. 7). Thus, the expectation is a matter that can be applied to a wide range of phenomena and events. Considering that, it can be addressed in the context of interactive dance as well. That means, in an interactive dance system, the device's output will build a sense of expectation in the dance, and in the next step, it is assumed when this expectation becomes disrupted, surprise occurs to the dancer.

Analyzing surprise on a phenomenological level, the human mind has evolved mechanisms for predicting the upcoming events, in order to become prepared for them, on a biological level. Those are *arousal* and *attention*. The arousal system controls mind and body parts and functions that associate with the movement. The attention system makes the brain to pay more attention to world events. These mechanisms should be considered in the design of the device's behavior, to provoke the dancer's emotions since emotions have a considerable influence on the dancer's cognition process (Tyng, et al., 2017).

Expectation is a temporal matter and it associates mainly with the questions of *what* and *when* things may happen. The uncertainty may accompany the questions of *where* and *why* as well. *where* in more spatialized operations and *why* regarding 'physiologically recent structures associated with conscious thought' (Huron, 2006, p. 7). Although Huron points that auditory expectation has played little role in musical organization and experience, but in an interactive dance performance, considering the development of technology and the progressive use of space and multi-channel playback systems (Qian, et al., 2004), they can be considered very relevant. In such a context, more questions involved, more enriched the device's behavior will present itself to the dancer's perception.

According to Huron, 'emotions evoked by expectation involve five functionally distinct physiological systems: *imagination*, *tension*, *prediction*, *reaction*, and *appraisal*' (Huron, 2006, p. 7). He proposes that each of these systems can evoke responses independently. However, he mentions that for any given situation, considering the temporal nature of expectation, these systems working together, arise a dynamically evolving sequence of feeling. The five response systems can be grouped into two periods or epochs:

- *pre-outcome responses*: feelings that occur prior to an expected/unexpected event - imagination, tension
- *post-outcome responses*: feelings that occur after an expected/unexpected event - prediction, reaction, and appraisal (Ibid., p. 8)

Further on, each of these systems, regarding the interactive dance system will be elaborated, and based on them, two main strategies to achieve the sense of surprise will be presented. Afterward, the functionality of those strategies in the creation of the sense of dialogue will be argued.

Firstly, imagining an outcome, in this case, the device's output, and the dancer's reactions and actions towards it, can allow him/her to feel an indirect pleasure, or displeasure though the outcome that has happened. The imagination response is one of the principal mechanisms in behavioral motivation since it makes it possible to make future outcomes emotionally noticeable. In other words, caring about negative or positive feelings helps the dancer to build a strategy to reach a more pleasant feeling in the future. In an interactive dance, imagining, allows the dancer to evolve its overall attitude and movements, regarding the device's behavior and the questions that can be raised concerning its actions and dynamic reactions (*what*, *when*, *why*, and *where*). If the dancer finds him/herself incapable of that matter, because of the device's behavior, his/her connection with the device would become petty and shallow, which is not optimal.

Secondly, concerning the tension system, 'preparing for an expected event typically involves both motor preparation (arousal) and perceptual preparation (attention)' (Ibid., p 9). The dancer matches arousal and attention to the expected outcome and tries to obtain a suitable level of them, for the expected event. Here, there is an uncertainty ongoing. This uncertainty is about what will happen, when or in more complicated setups, where and why it will happen. The dancer must control arousal or attention levels regarding the upcoming anticipated event, considering the aforementioned questions. If this takes too long, then he/she must sustain this tension until the predicted event - in this case, the device's action - happens. Thus, this uncertainty should not last long too much. Because a high amount of uncertainty takes a lot of energy form the dancer and it will create a sense of frustration in him/her. Put differently 'consequently, it would be adaptive for an organism to experience high tension responses as unpleasant. That is, even if only positive outcomes are possible, high uncertainty will lead to a certain amount of unpleasant stress' (Huron, 2006, p. 12).

This is a matter that needs to be avoided and considered in such an interactive system's design. But at the same time, it is important not to let the dancer feel entirely comfortable as well. Since this will draw the tension away and consequently, leads the dancer to complete control of the device and the parts in the aesthetic relationship.

Thirdly, as respect to the prediction, organisms respond better to expected events than unexpected ones. Here, the dancer's predictions help him/her to perceive the device's behavior more accurately and initiate appropriate motor responses more efficiently. Psychological evidence in support of a prediction response is found in the classic work of George Mandler. 'Confirmation of expected outcomes generally induces a positive emotional response even when the expected outcome is bad' (Ibid., p 13). Thus, prediction plays an important role in the aesthetic relationship of the dancer and the device. The device's behavior should not be completely predictable for the dancer. In other words, by disrupting the ability of the dancer to predict an upcoming event, the device can restrain his/her complete control over the interaction. That reduces his/her part in the interaction and adds to the device's one, in that regard.

The fourth one is the reaction response. It is very fast and is followed by a quick body response. Two of its characteristics that are more relevant to the context of interactive dance performance, is it being onset and not mediated by consciousness. (Ibid.) The surprise here arises from an inconsistency between an actual outcome (i.e., the device's behavior) and a highly practiced schema (Huron, 2006). In this case, these schemas relate to practiced motor skills of the dancer and his movements, regarding the device output. Therefore, when the device disrupts its normal behavior, the reflexive response that the dancer shows immediately to this action shall be categorized in this system.

The fifth one is the appraisal response. This response is more pensive in a way and thus, more dependent on environmental factors. This response is conscious and assessed. From a temporal perspective, it takes more time for the dancer to assess the device's behavior, reflect on it, and respond to it. Now, let us consider a situation that the device has several layers in its behavior. By layers, I am referring to different reactions that the device may have towards the dancer. From less complex, and usual reactions (superficial ones) to more complex, and dynamic ones (deeper ones). This complexity in dynamic reactions can be in various ways. Considering that matter, it takes more time for the dancer to build expectation regarding the deeper levels of the device's behavior. This may disrupt the process of reflecting on what the dancer has already assessed through time, from the device's behavior - which leads to his/her appraisal response - and disrupt his/her expectation. This matter, and the ways that the mentioned complexity can be created, will be addressed further, in one of the strategies offered, to create the sense of surprise in the dancer (i.e., dependent mapping system section).

These five response systems proposed by Huron, each regarding their distinct function, optimize human behavior and adaptation to its environment. Considering the interactive dance, each system's relevance was mentioned. Following, the mentioned argument regarding the notion of surprise will be briefly reviewed.

As it was mentioned, expectation is an innate matter to humans. In the interactive dance, the dancer develops a certain expectation from the device's behavior. This expectation is intertwined with *what*, *when*, *why*, and *where* things and events may occur, so he/she can be ready to have a suitable response to the device. Trying to allow the device to create a sense of surprise in the dancer, in the design process, each of these questions should be addressed. In the more complicated setups, a mixture of all these questions may be considered. These questions may be utilized in the physiological systems - imagination, tension, prediction, reaction, and appraisal - that are evoked by expectation. Each of those five systems has its distinctive functionality. Regarding interactive dance, imagination is an important matter to assure a prominent interaction. On the next step, it is important to maintain a level of tension that balances the level of comfort in the dancer in a way that he/she does not entirely feel in control. Concerning the matter of prediction, measures need to be taken, so that the device's behavior may not be completely predictable for the dancer. Dancer's responses are in two general ways, reaction and appraisal response. The first one refers to the dancer's quick reflexes which can be evoked by disrupting the normal device's behavior. Put differently, an unpredicted change that disrupts the dancer's expectation. The second one is a more thoughtful, long term response, which for its disruption, a more in-depth behavior is required from the device.

Further on, considering all the aforementioned psychological systems, two main strategies will be offered, to make the device able to disrupt the dancer's expectation from its behavior and surprise him/her. That may lead to disruption of the dancer's control on the device and let the device possess its part in the interactive relationship that they have. It is important to mention that regarding the design of the system, the aforementioned four questions need to be addressed. The strategies offered are randomness and dependent mapping system.

### 2.2.1 Randomness

Randomness in general terms is ‘a selection among alternatives is said to be strictly random if a prediction of any one of the possible outcomes is as justified or as well-founded as any other’ (Rescher, 1961, p. 1).

In this context, randomness applies to the way that the device generates its behavior. Also, the device’s behavior is occurring on a temporal level. Therefore, the randomness in the device’s behavior occurs on two levels: *generational* and *temporal*. To be more specific, by generational, I refer to the way that the device generates its output. Assuming the device’s motor is based on programming, randomizing certain values in the code that lead to random outputs, may lead to the randomization of the device’s behavior on a generational level. By temporal, I refer to occurring a certain or any other type of behavior randomly on random periods and lasting for random periods as well. This randomization of the device’s output, on both levels, shall disrupt the expectation that evolves in the dancer, during his/her interaction with the device.

Although, there is a point that needs to be addressed here. According to Huron ‘organisms are constantly trying to conserve energy. Bodies (including brains) drift toward low states of arousal when no action or thought is needed’ (Huron, 2006, p. 5). Also, according to Ayton and colleagues, ‘people’s apparently biased concepts may perhaps be...tuned to capitalize on properties of our environment. So, from an ecological viewpoint, perhaps repetition of outcomes is actually correctly considered to be more likely that alternation in non-random sequences’ (Ayton, et al., 1989, p. 223).

Thus, it can be stated that the dancer tries to manage his/her tension and energy level during the interaction with the device. This is a matter that is very much based on his/her expectation from the device’s behavior. Regarding that matter and considering the imagining system discussed above, the device needs to generate a behavior - to some extent, repetitive and/or consistent enough - so the dancer may be able to build his/her expectations upon it and maintain his/her interaction with the device.

But an entirely predictable behavior from the device will lead to the complete control of the dancer during the training process over the interaction and possession of parts in it. In order to prevent that matter, the device can utilize randomness in its behavior, which may lead to surprising the dancer. Behaving differently on a generational level and different temporal periods makes it more difficult for the dancer, to anticipate the device’s behavior. This includes the device’s actions and dynamic reactions towards the dancer. In both of those parts of the device’s behavior, one of the main constituent strategies that will surprise the dancer and affect his/her control level on the device is randomness. Randomness can cause an inconsistency between the device’s predicted output and the dancer’s trained motor skills and movements, and as it was discussed in the fourth psychological system, cause surprise in the form of a reflexive response.

However, too much randomness does not create an optimal outcome. As it was mentioned, too much of uncertainty, lead to too much tension - as a psychological system - in an ecologically based interaction, and eventually causes a sense of frustration in the dancer. This way the dancer finds him/herself unable to cope with the device’s behavior and may find him/herself in an incompetent condition. Also, too much randomness can be experienced as noise/chaos, sometimes even with a uniform quality as well (think of how you get white noise[3] from playing a sequence of random numbers). Further, in the implementation and design section, I shall describe how this strategy can be utilized in the design process, both on a generational and temporal level.

In the end, it has to be pointed out that the manner that the device changes its behavior may be drastic or gradual. Although it may be deduced, that the dance's response to drastic behavior change will probably be a reaction response. But the dancer can assess how to react to it during the interaction and have an appraisal response to it as well. The same applies to a gradual change in the device's behavior.

### 2.2.2 Dependent mapping system

In the previous section, the randomness and its effects on the dancer's response were discussed. Here, another strategy, concerning the psychological responses of the user will be elaborated. In a broad sense, the dependent mapping system is referred to as a changeable reaction from the device, regarding the same input from the dancer. This change has its roots in various spatial and/or temporal aspects of input from the dancer. Therefore, it can be included in the category of dynamic reactions as well.

This mapping system is inspired by Kristensen's work on the notion of *subjective behavior*. According to him, subjective behavior is:

> the intention to move further away from the programming language level (object-oriented modeling and design, which reflects to a large extent directly object-oriented programming) towards a more natural way for human beings to understand and describe application domains, among others based on concept formation (Kristensen, 2001, p. 13).

Objects behave objectively in the sense that the behavior of an object is known no matter the circumstances of invocation. 'With subjective behavior objects can display different behavior dependent on the circumstances - although still deterministic behavior' (Ibid., p. 19).

Inspired by the aforementioned argument, in the dependent mapping system, selected mappings display different behavior, dependent on different circumstances which will be explained further. This matter may add layers to the device's behavior. Earlier, I mentioned that an appraisal response requires a more layered, and complex behavior from the device. This strategy provides such a possibility for the device, so it may impact on the dancer's psychological systems on a wider scale. It helps the device, to reveal different layers of its behavior (i.e., dynamic reactions) to the dancer. Thus, the dancer may not obtain full control of the device's behavior, and take over the device's part in an excessive training procedure.

In the usual way, a certain movement will make the system behave in a certain way. But in this mapping system, that certain movement may cause different behaviors by the device.

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[3] In signal processing, white noise is a random signal having equal intensity at different frequencies, giving it a constant power spectral density (Mancini & Carter, 2009).

That difference can be caused by various factors which will be elaborated in different approaches to this system.

This may disrupt the assessment of the dancer, from the device's behavior, which leads to his/her appraisal response and disrupt his/her expectation. In other words, when the behavior of the device is already known by the dancer through time and is expected, the predictability is inevitable. But when another layer adds up and the device's response (i.e., dynamic reaction) starts to vary, based on different temporal or spatial factors in each condition, the sense of predictability gets disrupted and a sense of surprise shall be aroused. Therefore, this complexity (i.e., dependent mapping system) can play a significant role in reaching that sense.

This mapping system can be developed by two approaches. First, in-depth, by adding modes of interaction - space and time - as layers to a selected body movement parameter. Second, by expansion, including a combination of two or more body movement parameters in defining the behavior. An example of the first approach is a mapping that performs a different behavior concerning the same body movement, on different temporal levels and spaces. An example of the second one includes a movement mapping that is influenced by other movements of the body as well. Needless to say, a combination of those approaches can be used as well. In the practical work of this thesis, the device responds differently, in regards to the dancer's movement, based on the temporal aspect of the performance. As a consequence of that, the dancer deals with the questions, what will happen, and when and why it happens. It is beneficial to mention that randomness is also utilized in this strategy as well. This matter will be elaborated more in the implementation and design section.

Overall, regarding these strategies, it can be stated that randomness is utilized in the behaviors in the device, that are fully or partly independent of the user's control (i.e., actions and dynamic reactions). The dependent mapping system leads to a more complex behavior from the device that presents different behaviors, regarding the same action, in different circumstances. Both of these strategies are ought to disrupt the dancer's expectation of the device's behavior and create a sense of surprise in him/her, utilizing various psychological systems. This surprise may restrain his/her dominance in the interaction and adds to the device's possession of parts in the shared interaction. This possession, by both participants in the interaction, is a dynamic matter and may lead to a sense of dialogue between the participants, as it was defined before. However, this sense may be strained because of the limitations in the programming and system design.

It is important to mention that, Mullis states that much of the work done on this topic emphasizes the dancer's phenomenological experience of interactivity but does not sufficiently consider the nature of the devices and platforms that make such experiences possible (Mullis, 2013). But this issue has been addressed in this argument. Also, the mentioned measures may help to expand more on the sense of bidirectionality in the interactive system, as Birringer discusses that as a manner in which dancers can shift their attention away from their internal body awareness to the environment conceived and experienced, not as a 'given space but rather [as] a shifting relational architecture that influences her and that she shapes or that in turn shapes her' (Birringer, 2004).

Needless to say, the dancer needs to train with the device to reach a level of familiarity with its behavior, to be able to interact with it. As a consequence of that, a question can be raised: 'How much time is required for the dancer to get to know the device's behavior, in a sense that its behavior would not surprise him/her, and following that, become able to possess all the parts in the interaction and abolish the sense of dialogue?'

The logical answer to this question depends on the cognitive capability of the dancer and his/her abilities to overcome the sense of surprise, created by the actions and dynamic reactions of the device, and possess his/her part in the interaction. I believe that overcoming the randomness in the device's behavior depends on the dancer's cognitive skills, and is very unlikely. Although it is a matter that needs to be investigated on an empirical level as well. The answer also depends on another device's available option to counteract and claim its part in this aesthetic relationship. This option consists of increasing the complication of the dependent mapping system and including more layers (in-depth), including various modes of interaction in it (i.e., space, and time) and also to expand it, including a combination of two or more body movements parameters in defining a certain behavior. That leads to the creation of more questions for the dancer to address and creates more complexity in the device's behavior and affects - or disrupts - the assessments and responses of the dancer. This way, the possibility of the device being overruled by the dancer, through excessive training becomes less likely.

In conclusion, it can be stated that the parts that the dancer or device can possess in the interaction, and the amount of the time that is required for the dancer to get to know the device's behavior, in a sense that its behavior would not surprise him/her, depends on two main of factors:

- Skills of the dancer, and the level of his/her cognitive skills
- The amount of complication of the dependant mapping technique in depth (layering) and expansion

Here, this needs to be addressed that there the ability of the dancer to cope with the device's behavior is different than to master it. The idea is that the dancer can cope with the device's behavior in the sense that he/she will accept the notion of surprise in the device's behavior and its active part in the interaction. On the other hand, mastering the device's behavior refers to the situation in which the dancer does not sense the surprise in the device's behavior and feels completely in control of the active part of the interaction.

Despite the logical conclusion regarding the proposed question, putting it into practice and evaluating the practical work and answering the question, based on the practical results can be of significant importance. This matter will be addressed in the implementation and design section, and further on, in the evaluation of the practical work one.

# 3 Methodology

As stated in the introduction, the main objective of this thesis is to study how the interaction between the performer and device in an interactive dance system can convey a sense of dialogue to the dancer, by the use of surprise, utilizing body, space, and time in the context of Hip-Hop art. The following research strategies are used in order to argue the research question, put it to practice, and evaluate the research results.

## 3.1 Artistic research

A research form that:

> unites the artistic and the academic in an enterprise that impacts on both domains. Art thereby transcends its former limits, aiming through the research to contribute to thinking and understanding. Academia, for its part, opens up its boundaries to forms of thinking and understanding that are interwoven with artistic practices (Borgdorff, 2012, p. 44).

After defining the theoretical framework and the argument, in order to refine and fortitude the theoretical research, I will implement the theoretical discussion, via a certain design strategy in an interactive dance system. This will be done via collaboration with a Hip-Hop dancer. The outcomes of this collaboration will be documented. This documentation includes the dialogue between the designer and the dancer, to achieve the most suitable practical design concerning the thesis research question. It has to be mentioned that this project is not artistic research per se, in that it isn't primarily "research in and through the arts", as Borgdorff writes, but still has artistic aspects and involves aesthetical perspectives.

## 3.2 Design methodology

The method that is chosen for the design of the practical work, in this thesis, is based on Park and Boland's work, more in the details, two of their proposed interaction models[4]: *interaction of designers* and *mutual interaction between designers and users* (Park & Boland Jr., 2011). There will be two phases in the design process. *Initial phase* and *Iteration phase*.

In the initial design phase, the first model will be addressed. This model elaborates on the designer skills, his/her understanding of the users, and finally the prototypes he/she designs. In the iteration phase, the mutual understanding and constructive work between the designer and the dancer is the matter of concern, which fits into the second model of the design proposed by them. The other design model that is being used in this phase is the *iterative design*. Regarding the practical work, according to Nielsen, it can be stated that usability experts cannot design perfect user interfaces in a single attempt, so a usability engineering lifecycle should be built around the concept of iteration (Nielsen, 1992). In respect to the definition of iterative design, he mentions that 'iterative development of user interfaces involves steady refinement of the design based on user testing and other evaluation methods'

[4] Interaction of Designers, Interaction of Users, and Mutual Interaction Between Designers and Users (Park & Boland Jr., 2011).

(Nielsen, 1993, p. 32). However, here, this approach will be used not based on the user's feedback, but in the interaction with the dancer/co-designer.

Also, based on Bevilacqua and colleague's work, the classification of the different approaches for sensing gestures in dance performance, using three main categories, *body*, *space*, and *tim*e will be utilized in the design process. 'This classification helps to clarify the metaphors implicitly or explicitly related to interactive system' (Bevilacqua, et al., 2011, p. 184), in order to build an interactive system that serves the research goal. Overall, the mentioned methods will be put to use, to reach the objective of the research. This matter will explicitly be addressed in the implementation and design section.

## 3.3 Survey

Survey refers to 'the collection of information from a sample of individuals through their responses to questions' (Check & Schutt, 2012). Survey research is a promising strategy to gain information regarding human behavior (Singleton & Straits, 2009) and can be a very resourceful way to acquire feedback from the dancers, interacting with the designed system. It 'can use quantitative research strategies (e.g., using questionnaires with numerically rated items), qualitative research strategies (e.g., using open-ended questions), or both strategies (i.e., mixed methods)' (Ponto, 2015, p. 168). In this research, a mixed-method will be chosen. The reason for choosing the quantitative strategy in the survey is to ease the process of reflecting on the system for the users and also analyzing the data for the researcher, afterward. However, considering that elaborative feedback from the users, regarding the succession of the system, is necessary, including a limited amount of open-ended questions can be very beneficial. That is why a mixed method is chosen here.

However, due to the Coronavirus pandemic, there were limitations regarding the implementation of this method and I managed to only have access to one user. This matter will be addressed in the evaluation of the practical work section.

## 3.4 Technical implementation and tools

The technical procedure in the design process and execution of the practical part of the thesis includes several steps. Starting from the device's sensors, there are various methods to capture the movement's data. Sensors are the sense organs of a machine. 'Through its sensing inputs, a machine can communicate with its environment and therefore be controlled' (Bongers, 2000). The sensors used in the thesis's system are BITtalino R-IoT sensors (Bitalino, n.d.), a contact microphone, and a condenser one.


*Figure 3.1: Left to right: BITalino R-IoT, condenser microphone, contact microphone*

The reason for choosing the BITalino R-IoT sensor was mainly to have a small, portable, inclusive, and wireless sensor that could be mounted on the dancer’s body, to register his/her body movements. The BITalino R-IoT embeds a 9-axis digital IMU sensor[5], featuring a 3-axis accelerometer, a 3-axis gyroscope, a 3-axis magnetometer, and a 3-axis Euler angle measurement, allowing onboard computation of the absolute orientation of the module in space. In the final design of the system in this thesis, the Euler angles and the accelerometer input values are used. Euler angles values - Yaw and Roll - are used for tracking the orientation of the hand movements of the dancer, in order to use them for manipulation of the played back sounds and video outputs. Accelerometers measure the acceleration force in three axes, in which two of them - X and Y - and also their combination are utilized in triggering events and adding depth in the dependant mapping system. The reason for choosing those values, in each stage of the design, will be elaborated in the implementation and design section.

The sensors are tied above the dancer’s wrist and get the data from the dancer’s hand movement. The reason for that matter will be elaborated in the implementation and design section as well. They are connected to a router via Wi-Fi and send the data via the router, to the operating computer, using an ethernet cable. The data is received in the programming environment via UDP[6], scaled in the device, and used in sonification and playback of sounds and manipulation of various effect parameters, implemented on audio and video materials in the system. For the programming, MAX/MSP (Cycling ’74, n.d.) is the considered option, considering its efficiency for working with both audio and video materials and also its suitable and convenient user interface.

[5] “An Inertial Measurement Unit, commonly known as an IMU, is an electronic device that measures and reports orientation, velocity, and gravitational forces through the use of accelerometers and gyroscopes and often magnetometers” (Sparton, 2015).
[6] “UDP (User Datagram Protocol) is a communications protocol that is primarily used for establishing low-latency and loss-tolerating connections between applications on the internet” (Rouse, 2020).

Also, the auditory inputs (i.e., microphones) are used to expand the modalities used in the interaction between the device and the dancer and are utilized in triggering the events. Hence, sound impulses are used for that purpose. This will be elaborated more in the implementation and design section.

The output can be perceived for the dancer via device's actuators (i.e., speakers and projection) and provide the audio/visual material for the dancer. The sound is going to be processed in mostly two ways and a combination of them: triggering sound events, and continuous control of sound grains. (Bevilacqua, et al., 2011) The triggering method is used for making abrupt changes in the device's output and starting and finishing the performance. The continuous method is used for manipulation of the audio-visual outputs of the device since it provides more control over the manipulation process, overtime, or in a spatial dimension.

Regarding the visual aspects, the intention is to project a short movie of 'outside the water (i.e., surface)' and 'under the water', flipping randomly on the wall, which represents the sea-level rise during the performance. The dancer (perhaps representing mankind) may/may not dance in relationship to that picture and adjust his movements into the outside of and beneath the water environment, to express his feelings in that regard, and the subject of the performance. An overview of the system can be observed in figure 3.2:

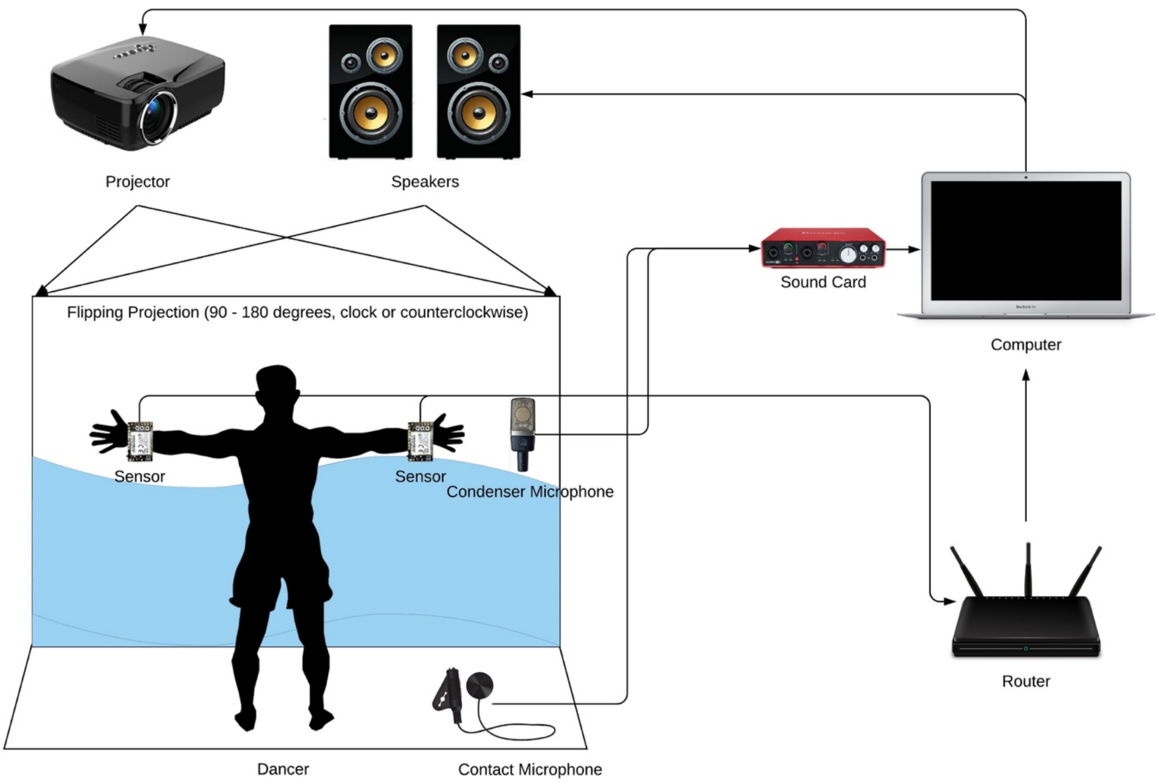


*Figure 3.2: Thesis practical interactive system overview*

During the practical work design and testing process, the theoretical framework and research objective will be applied. Also, the design shall be done in a way that it could be possible for the work to be performed in various environments, serving its subject.

# 4 Implementation and Design

After defining the theoretical framework and methodology, the next step is to design the system in a way that provides the most suitable results, regarding the main objective. This endeavor is made to fortitude the research proposed argument, beyond a purely logical and theoretical level. As it was mentioned, according to Bevilacqua and colleagues, the procedure of design involves the classification of the different approaches for sensing gesture as used in dance performance, using three main categories, body, space, and time (Bevilacqua, et al., 2011). Following, each category will be explained and their use in the design process will be elaborated.

Body: It involves the dancer's posture and movement and how they can be captured. Of course, sensors and video systems are efficient tools in capturing postures and movements of the entire body remotely. However, tracking movements via video systems is not relevant in this thesis, but sensors are used to track the dancer's hand movements.

Space: Defining particular zones of the space, in which the presence of the user triggers specific electronic events. 'Space-based interaction implies structuring the space, and associating audio/video processes with specific spatial location' (Ibid., p. 188). In this category, commons paradigms could be the presence or absence of the body in certain spaces, crossing borders, entering and leaving zones, and so on.

Time: It is argued that temporal interaction can be put forward in a similar fashion as spatial interaction (Bevilacqua, 2007). Similar to spatial limits or zones, time limits and time moments can be defined. Although here, temporal events, time sequences, and synchronization mechanisms drive the interaction in the system.

Now, utilizing the categories mentioned above, the strategies for implying surprise and further on a sense of dialogue, considering Park and Boland's (2011) interaction models, will be implemented in the design. During this process, two implemented phases will be discussed: Initial design and Iteration phase.

In the initial phase, based on the previous research that has been done in this area, mostly the artistic ones, and the designer's experience, the prototype was designed. Of course, the design was set according to the subject of the performance. That means certain elements in the interactive design represented the main subject. This was done, to provide the co-designer, which is a dancer, a suitable platform to start the interaction with it, and that is where phase two came into the action.

In the second phase, based on the mutual understanding between the designer and the user (dancer), the system was designed and improved through an iterative approach. The design was developed in a way to convey a sense of dialogue in the interaction to the dancer, using the element of surprise. Further, by getting feedback from the dancer, the design was improved during the iteration process and provided a refined system regarding the main objective. The iteration process included conversations with the dancer that lead to a better understanding of the user, from the designer's perspective. But, due to the Coronavirus pandemic and the Norwegian University of Science and Technology's restrictions regarding that, the physical contact with the co-designer to perform this iteration became limited and its time frame was moved to after the evaluation procedure. This matter will be pointed out in the iteration phase section.

## 4.1 Initial design

In the initial design phase, the first model of Park and Boland's work was utilized. It has three main principles. First *design professionalism*, which refers to having a series of detailed design skills and involves design logic that subsequently creates analytic and partly empirical knowledge in the process of design actions (Herbert A., 1996); then, *understanding users*, which involves considering their needs in the core of the design (Park & Boland Jr., 2011); and finally, *design prototypes*, which refers to the indication that designers encounter a variety of design conflicts in a design project, and that designers seek to coordinate these conflicts to move forward through different design stages (Jones, 1992).

Considering the design professionalism, the designer has to understand the user of the system, the dancer, and its requirements and needs as certain goals in the process of design. That will eventually lead to the design of prototypes. It would be optimal to have various prototypes with diverse probabilities available for the dancer/co-designer to experiment with, considering the design environment and subject of the work. But due to pragmatic issues, that was not possible. However, one prototype was created, so the co-designer could try it, and collaborate in the design, in the iteration phase.

In the practical work of the thesis, the intension to reach a sense of dialogue between the dancer and the device was ought to become possible, by the use of surprise. The sense of surprise in the design was supposed to be elicited from the afore discussed strategies - randomness and dependent mapping system. These strategies were ought to put into practice, via manipulation of the synthesized sound and visuals in a way that the dancer was not expecting it. However, in the initial phase, the prototype was utilizing randomness strategy, only in its visual aspect. Therefore, from the audio aspect, it was acting responsively towards the dancer's movements. The reason for that was to provide a prototype that the co-designer could try it, and it would be considered as a platform to be developed further, considering the abovementioned strategies, via collaboration and dialogue with the co-designer. That would have led to a more efficient milestone regarding the design of the system.

The device's inputs (i.e., sensors) in this system consisted of IMU sensors and auditory inputs. The device's outputs (i.e., actuators) consisted of audio and visual outputs. Following, they will be elaborated in their respected sub-sections.

### 4.1.1 Device's inputs

#### *4.1.1.1 BITalino R-Iot Sensors*

Regarding the inputs to the device, two IMU sensors were considered to track the dancer's hand movements. It was important to define the placement of the sensors. This could vary from one style of dance to the other. In the context of Hip-Hop dance, according to the Kojima and colleagues, the presence of emotion is shown mostly on the speed of the right and left elbow joints and overall upper limbs, rather than on the lower ones (Kojima, et al., 2016). Also, in free dance style, it is suggested that the hands express the feelings via impulsivity (speed amplitude range), speed, acceleration, and extension (Dyck, et al., 2013). Considering the mentioned points, right above the wrists were chosen as the most suitable position to place the sensors.

The sensors sent the movement data to the device. Between all the available data coming from the sensor, for the first step, based on the ease of scaling and use and the abovementioned reasoning, the acceleration inputs were chosen. They were used in triggering and continuous manipulation of the sound events. Regarding triggering sound events, a very rapid and highly accelerated movement of the hand in the X-axis, above a certain threshold of acceleration, triggered a parameter in the device on and off.

#### *4.1.1.2 Auditory inputs*

As it was mentioned, auditory inputs were used in triggering the events by utilizing the sound impulses. A convenient way to create impulses by the dancer was to use his/her hands and/or feet. Thus, for the impulsive sound created by hands - claps - the condenser microphone was considered, since condenser microphones have a good transient response and are sensitive to loud sounds (Shambro, 2019). For the impulsive sounds created by the feet - foot-banging - a contact microphone was used since this microphone is designed to be in physical contact with the object producing sound. Here, it received the foot-banging sound via the ground. ‘A contact mic receives and derives its audio signal from mechanical vibrations instead of airborne sound waves’ (Sweetwater, 2017). Therefore, it was highly unlikely for it to pick-up impulses from the clapping and other probable sources. Also, there was a certain threshold defined for the impulse levels, so the device would react to impulses above that. The placement of the microphones is presented in figure 4.1:


*Figure 4.1: Placement of the microphones*

### 4.1.2 Device's outputs

The device was ought to respond to the dancer's movements and behave in an audio/visual way.

#### *4.1.2.1 Visuals*

The visuals included footage of water surface, half below and a half above the water, representing the sea-level rise. The rising started from one side of the projection and continued till it reached to the other end (filled out the projection). It can be observed in figure 4.2:

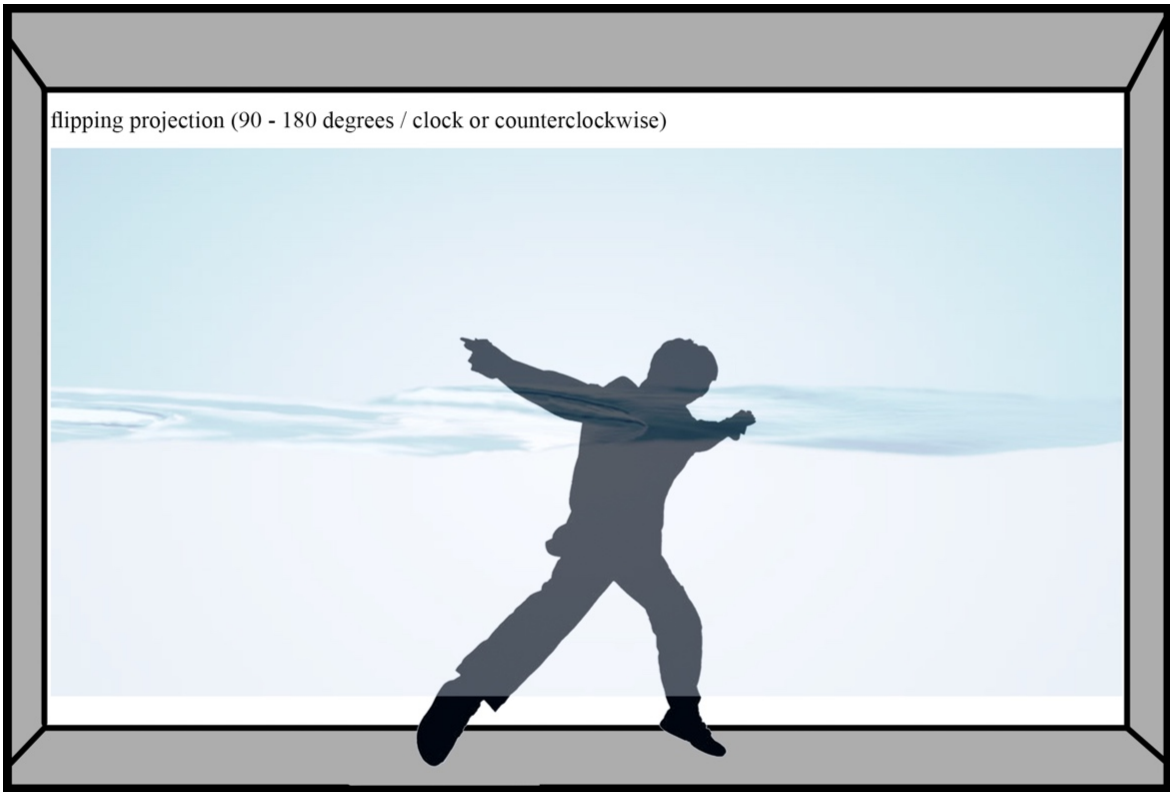


*Figure 4.2: Water-level rise projection*

The speed was set to a rate, so it would take several (adjustable) minutes for the video to present a full underwater image. The video was projected on a wall and the dancer himself. Also, it flipped randomly - time-wise and axis-wise - so in the case, the dancer desired to interact with it, he/she would experience uncertainty regarding when and where the surface of the rising water would be. Thereby, he/she could sense a lack of control, in his/her interaction with the visual action of the device.

The video was pixelated to present an abstract form, to some extent, and to prevent a full representation. According to Rancière, the influence of representation in the art on its audience has not a definite answer since it is based on the effort to provoke feelings that the performers, or in this case, the performer and device, do not necessarily have (Rancière, 2010). However, that being said, having shreds of representation allows the system to inculcate the subject of the performance. The setup, including the projection, is presented in figures 4.3 and 4.4. However, unfortunately, the quality of the images is not optimal. That is because of the darkness and lack of light, in the performance environment.

*Figure 4.3: Performance setup 1*

*Figure 4.4: Performance setup 2*

#### 4.1.2.2 Audio

Regarding the audio aspect of the device output, I planned for some of the sounds to be played independently of the dancer's input. A lifeline[7] that consisted of an underwater sound and an ambient sea sound that was filtered out, in sync with the water level rise in the visuals. The water level rise in the visuals was tracked by color-tracking and was linked to a high pass filter which filtered out higher frequency areas of the ambient sea sound spectrum, by rising the sea-level, making the sound darker and less bright as it rose. Also, an underwater sound was played back, which its level had a direct relationship with the high pass filter on the ambient sea sound and as the filtering amount rose, the level of underwater sound rose as well. In other words, with raising the water level, more ambient sea sound was filtered and the level of underwater sound was raised and it became more audible and dominant. This procedure is presented in the sound sample, named "Transition between above the surface and underwater sound", available in the blog (see Appendix 1).

In addition to the lifeline, every other sound in the performance was affected by the dancer's movements since as it was mentioned, regarding the audio aspect of the device in the initial design, the focus was on building the responsive behavior of it, in other words, its reactions. Therefore, foreseeing the dancer's movements had a key role in this phase.

The effectors were received by sensors (i.e., BITalino sensors and microphones) and used in synthesizing sounds, playing back samples, and triggering effects on the played back material. The auditory output provided the material for the dancer to dance to. Overall, regarding the sound output, the device had three types of reactions:

- Sonification of the data and synthesizing the sounds
- Triggering samples
- Implementing effects on the samples

Starting with the sonification of the data, the effort in this phase was to design the device's behavior, in a way that could be suitable for a Hip-Hop dancer's movements. Rhythm is the backbone of Hip-Hop dance. Therefore, the mappings were designed in a way that the dancer could create a Drum rhythm, and loop it by using impulsive sounds (i.e., clapping and foot-banging) that he created. Since the Drum instrument was designed in a way that the dancer was in charge of creating the rhythm, he/she was the one who could define the tempo as well. This would define a temporal interaction between him/her and the device and make his/her synchronization process with the device more efficient since he was in control of it. The number of instances that the dancer was able to create rhythms with various tempos was unlimited. The instrument chosen for the synthesization of the sounds was Piano. The reason for choosing that instrument was that it was simple to implement and would work for the initial test. The mentioned sonifications are presented under the names of "Piano sonification" and "Drum sonification" in the blog (see Appendices 2 and 3).

Moving on to triggering samples, the impulsive sounds were using a certain sound level threshold to trigger the synthesization process on and off. They had to be generated, close to the microphones (condenser and contact microphones) that were available in the performance

[7] By lifeline I am referring to a sound or combination of several sounds, with any possible nature (mostly ambient) that is present during the entire time, in a performance.

stage. Therefore, the space around the microphones was a suitable zone for making those sounds and the dancer had to act in those zones.

Regarding the effects, there was one provided for the dancer, so he could implement it on the Drum rhythm. The effect chosen was the delay since delay manipulated the sound on a temporal level, in here on the generated rhythm, and provided the possibility for the dancer to play around with the rhythm texture in the performance. The control on Piano and effect parameters was mapped to the hand movements. Those could be considered as the continuous sound controls that were implemented in the prototype.

As it could be observed, the only utilization of the strategies defined for the creation of the surprise in this phase, was the use of randomness in the visual actions of the device, on a temporal and spatial level. Flipping the video which affects the spatial properties of it and doing it in random periods, which affects the temporal properties of it. Certainly, that was not enough. However, as it was mentioned this prototype was supposed to be expanded and refined by collaboration with the dancer/co-designer. Further on, the mappings implemented in the initial design will be discussed.

#### *4.1.2.3 Initial design mappings:*

The basic mapping strategies used in the initial design of the performance were one to one and divergent mapping. One to one mapping refers to mapping one data value to one function in the device, and divergent mapping is mapping one data feature to several synthesis parameters. It was first introduced by Kramer (Kramer, 1993) and according to Hermann, 'the motivation behind this approach is to account for the fact that idiophonic objects usually change their sound characteristics in several aspects at the same time when varying, for instance, the amount of energy input' (Hermann, et al., 2011, p. 370). Here, alongside one to one mapping system, specific data values and sound inputs were mapped into various parameters, to reach more efficiency in the design and enrich the device's behavior.

The right hand was in control of the synthesized Piano sound, controlling its velocity and pitch, and Drum samples playback. Regarding the Piano sound, it could be triggered on and off, via a rapid acceleration of the hand's movement, above a certain value of acceleration - defined by the designer's discretion. Regarding the Drum loop, to record the generated samples and play it back, foot-banging was used, as a trigger. Clapping worked as a triggering switch function, between the Piano and Drum sound. That was because the Drum rhythm, after being created by the dancer, needed to be recorded, and then looped, so the dancer could dance with it. Therefore, in the period that it was being created and recorded, the mappings of hand movement values, needed to be switched from Piano to Drum. In other words, the Piano needed to become muted, so the process of creation of the rhythm would not be disrupted by it. After recording the Drum and starting the loop, the dancer could switch back to the Piano sound, to dance with the rhythm and control the Piano sound with his hand movement. At that time, since the Piano was engaged, the hand movement did not function as controls for triggering the Drum sounds - to create the rhythm. This procedure performed optimally, plus the lifeline is presented in an audio example in the blog, by the name of "Initial design audio output" (see Appendix 4).

The left hand was in control of the delay effect, being implemented on the Drum generated rhythm, controlling the delay time and feedback. Because of technical difficulties, the use of Euler angles values, to register the dancer's movements, was not implemented in this phase. However, they were utilized in the next phase which I will describe in the next section.

Listed below, are the mappings done in the initial design. Also, figure 4.5 is presented to illustrate the way the sensors were receiving the dancer's movements.

- Clapping: Switching between the Piano and the Drum
- Right-hand movements:
  - Acceleration (X-axis): Piano pitch / Drum samples for generating the rhythm
  - Acceleration (Y-axis): Piano velocity (up to zero)
  - Acceleration (X-axis): Piano engagement (triggering on and off)
- Left-hand movements:
  - Acceleration (X-axis): delay time (1 to 1000ms)
  - Acceleration (Y-axis): delay feedback
  - Acceleration (X-axis): delay engagement (triggering on and off)
- Foot-banging:
  - 1st bang: Starting the recording of transient samples
  - 2nd bang: Stops the recording and plays back the file, looping it
  - 3rd bang: Stops the playback and starts recording again
  - 4th bang: Stops the recording and plays back the file, looping it (to stop the playback of the transient sounds loop, the dancer needs to create a silent loop)

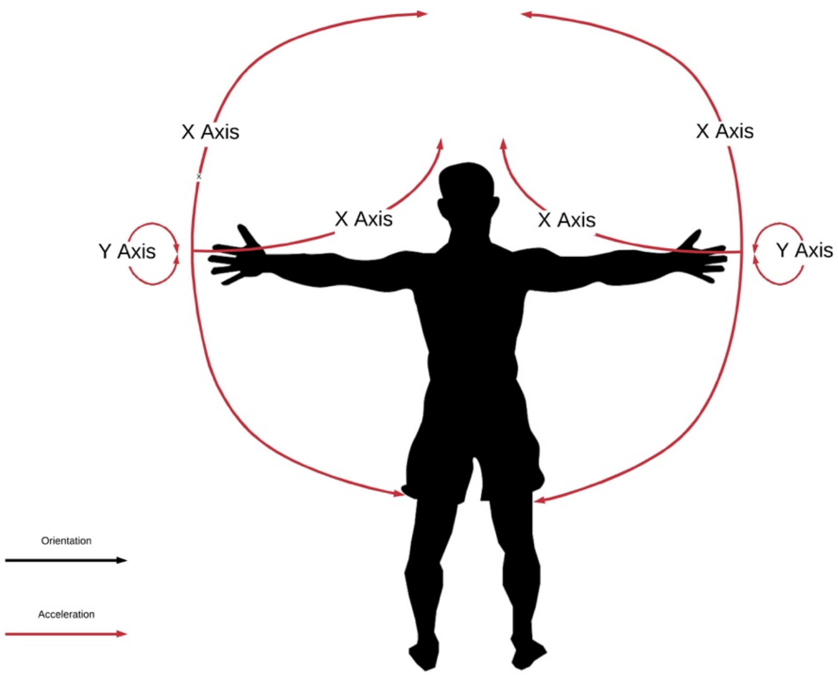


*Figure 4.5: Initial design's device inputs from the dancer's movements*

Also, the design flowchart is presented in figure 4.6:

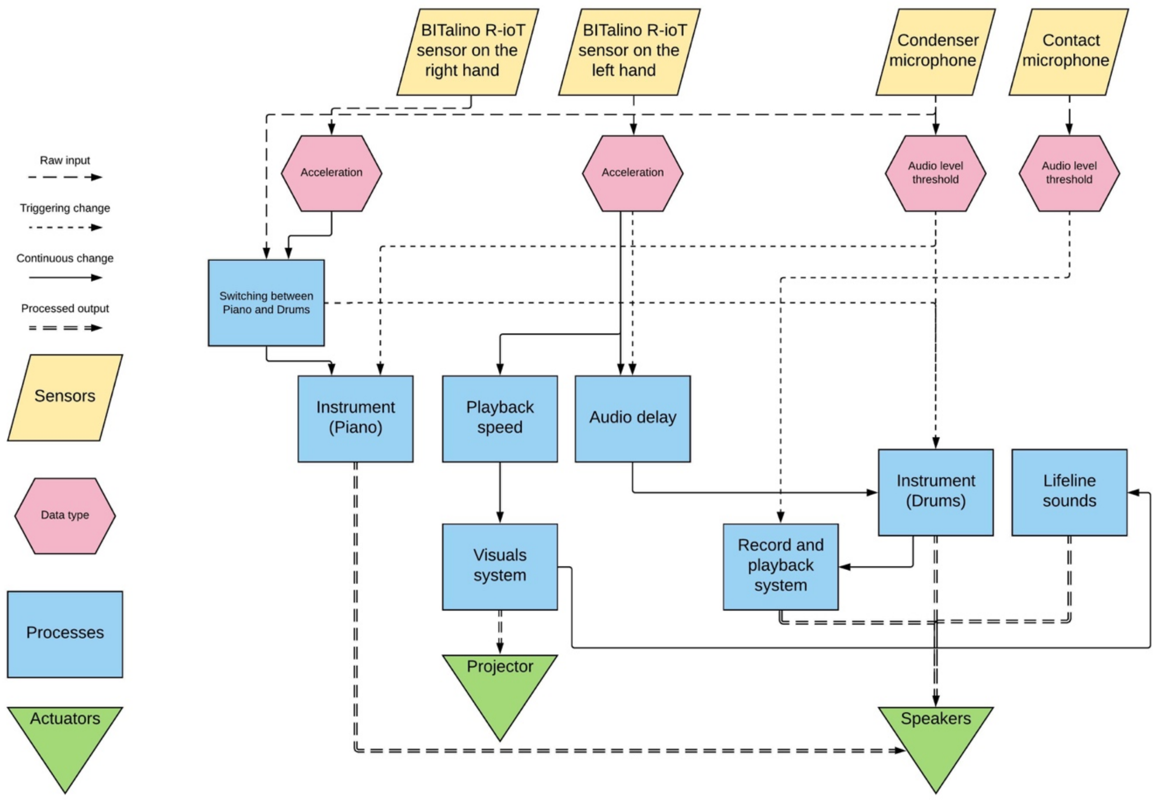


*Figure 4.6: Initial design's flowchart*

The practical outcomes and evaluation of the initial design will be elaborated more in the next section since it is a matter that needed the co-designer's assessment. Moving on to the second phase, the second utilized interaction model of Park and Boland's played a key role in the process; and that was the mutual interaction between designers and users.

This mode refers to interactions between the designer of the device and the user/dancer, that characterize a model of mutual interaction between them:

> This designer-user interaction model references dynamic design narratives and potential by presenting different interpretations between designers and users in a design project…the proposed design maturity concept includes the meanings of dynamic interactive paths stemming from designers and users in a design project. The interactive paths combine different modes of interaction between designers and users (Park & Boland Jr., 2011, p. 7).

The next phase of the system design is based on that argument and will be discussed in the following section, iteration phase.

## 4.2 Iteration phase

The process of design, in the interactive dance, is challenging. That is because 'both dance and computing are in themselves full of complexity, thus to create a cohesive union of the two involves much trial and error and a mutual disciplinary understanding' (Gonzalez, et al., 2012, p. 398). That is when the harmony between the dancer and designer finds its importance:

> Harmony emerges as experts from one domain learn enough about the other domain to make contributions with recognizable value in that other domain…when technology is introduced into the formal dance production process, a new set of considerations emerge for the choreography and the dance piece as a whole (Ibid., p. 398).

### 4.2.1 First iteration

It can be observed that the aforementioned mutual understanding leads to the realization of a set of considerations regarding the choreography of the dancer's movement. These considerations include improvisation as well since the dancer needs to be aware of his movement's effect on the device's behavior. 'It is possible to argue that in any interactive dance system, the technical constraints related to the chosen gesture capture apparatus influences the choreographic work' (Bevilacqua, et al., 2011, p. 184). Therefore, the system should be designed in a way to be as adaptable and efficient regarding the type of dance that it is being designed for. Thus, it was considered in the initial design phase, that the dancer will be allowed to move in more freely, in response to the sound he/she is hearing from the device, so he/she would not be obliged to monitor all his/her movements. This matter is addressed by, scaling, smoothing, the dancer's movements data values, and designing the mappings, based on the mutual understanding between the designer and the dancer/co-designer. Also, to obtain this movement data (i.e., rotation values), the mentioned technical difficulties were overcome, and Euler angles values were used, as the most efficient way to register the required dancer's hand movements orientations. That is because:

> each rotation in three-dimensional space keeps not only a point but a whole line fixed, and each rotation can be realized as a suite of three consecutive elemental rotations about coordinate axes. These two results are at the origin of the rotation descriptions given by so-called…Euler angles, respectively (Urzhumtsevaa & Urzhumtsevc, 2019, p. 870).

Following, the change made in registering the hand movements can be observed in figure 4.7:

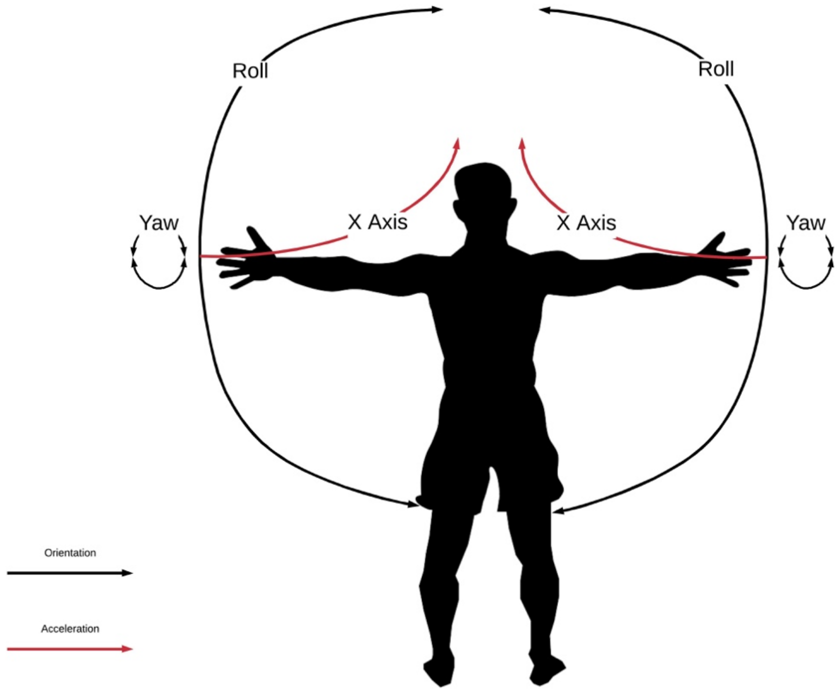


*Figure 4.7: First iteration's device inputs from the dancer's movements*

The mutual understanding was gained through the collaboration with a dancer in the design procedure. That means, in this case, the dancer, acted as a co-designer, and interacted, trained with the prototype. This matter suggested a more promising outcome, rooted in refinements from an actual Hip-Hop dancer. It also helped to refine the design, regarding the research argument - the creation of a sense of dialogue in the interaction with the users - as well.

Despite all the predictions regarding the device's behavior, in the practice, the experience was much different. How the dancer could relate to the device and how the device responded and acted towards the dancer varied in comparison with the designer's imagination. Certainly, this is a matter that is dependent on understanding the users model, and regarding this project, despite the experience and predictions of the designer, it was noticeable. Therefore, in the practical part of the research, the mutual understanding between designers and users model played a significant role.

The designer had one session with the Hip-Hop dancer/co-designer, Abdullah Ghazanfar, and tested the initial design. The discussion with the dancer and the feedback from him had an important role in developing the design and proving the point that how much surprise can be important, in convincing the dancer that the system is acting more independent and is not only reacting responsively.

After wearing the sensors and starting to move, getting familiar with the device's behavior, the dancer conducted several movements to establish a relationship with the device. This is a procedure that leads to the control of the dancer over the device, in the case the device does not claim its part in the interaction. In other words, without any measures taken from the device's side, by going down this path, the dancer and the device will be in a condition that in the feedback loop, the dancer is having complete control in the interaction, using his body as an instrument. But the aim is to disrupt that procedure.

In the first step, after Abdullah tried the system, some practical points were raised by him that I did not consider in the initial design phase. Considering the familiarity of the designer with the type of the dance and implementing the design in a way that it would be functional regarding that, still in the practice, a dancer's approach - in a general sense - as a professional in the field, may vary. After the dancer engaged with the system, on the bright side, he could communicate easily and efficiently regarding some aspects of the device; and on the contrary, he revealed some flaws in the system that could not be predicted during the initial design phase. Following, the flaws and bright sides of the design will be elaborated.

Firstly, it was deduced that the use of the Drum, being controlled by the dancer was not a prominent idea, since it increased the control of the dancer over the device. Also, it did not work as it was expected as well. The reaction of the device to the dancer's movement was very slow and not consistent. The reason for that matter was the data values smoothing process. Also, it was not as intuitive as it was considered in the initial design phase. Secondly, the smoothing process had negative effects on controlling the piano as well. And thirdly, the delay effect was not a suitable choice, considering the user's movement control and its outcome, being utilized by the dancer. The bright sides of the design are as followed. Firstly, the dancer was pleased with the instrument chosen for his right hand's movements, sonically, and control-wise. Secondly, the auditory triggering system worked well from his perspective and was intuitive for him.

Becoming aware of the mentioned points was the first step. After that, the discussion and followed by it, solutions revolved around enhancing two areas of focus in the design: technical and conceptual aspects. Starting from the technical perspective, the responsiveness of the system regarding latency was fixed by the reduction of the data values smoothing process. The Drum was removed from the patch and by consulting with the dancer and was replaced by premade beats. The delay effect was replaced with a reverb effect for aesthetical reasons and to allow the dancer to manipulate the sonic texture of the played back beat, in relationship to the underwater atmosphere. The reverb mix was matched with a delay on the visuals so that it could have a cooperative visual element as well.

Discussing conceptual aspects of the design, revealed new potentials and guidelines for the designer to refine the system. The discussion revolved around the behavior of the device. As mentioned, surprise was supposed to be used to imply a sense of disruption in the dancer's control, to provide a chance for the device to take its part in the interaction. That is ought to lead to a sense of dialogue in the interaction. The main point that was addressed in the discussion, was randomness. As discussed above, surprise is caused by disrupting the prediction and introducing new or impulsive elements. The following points in the iteration phase were raised to address that matter. These points were ought to be performed by the device, independently, and not to be controlled by the dancer's movements. Some were related to the audio aspect of the design and some to the video aspect of it:

Starting with the audio aspect, the first point was to include several beats with various tempos in the design, played back randomly by the device, for an unpredictable and random period.

The second point was to change the tempo of the beats on a random base, for random periods. Regarding the video aspect, implementation of visual effects (i.e., shuffling red lights) on a random base, on the video playback was the main point that was raised.

Therefore, randomness on both temporal and generational levels became the main concern in the development of the patch. After the mentioned considerations, the dancer was in control of the initiation of the sound (i.e., beats and lifeline) playback. But he was not in control of choosing which beat to be played and its tempo change. Although he was partly in control of playing back the next beat, besides the device, or put differently, both were in control of changing the beats. In the patch, three beats were programed to be played back on a random base (generational), for a random period (temporal) - between twenty and forty seconds - and then the device played back another beat. Also, the tempo started to shift on a random base every twenty to forty seconds, and the speed change was varying between twenty percent to three hundred percent, in a five to ten seconds period (temporal). Considering those measures, it can be observed that the device, to some extent, acted independently in regards to the dancer's movements, and was not behaving like an instrument that the dancer controls it with his body.

However, as it was mentioned in the randomness section, too much randomness may lead to the frustration of the dancer. This matter will disrupt the cognitive and sense-making process too much, that the dancer may not be able to establish an interaction with the device's behavior and may feel disconnected to it. It is important to consider a minimum amount of repetitions and definable patterns in the device's behavior to generate the expectation in the dancer, but not too much that it becomes entirely predictable. Hence, the periods that were defined for the device to trigger various changes in its behavior - audio/visual outputs - were based on both the designer and co-designer/dancer's logic and perception of predictability in the interaction with the device.

This must be mentioned that the use of body and time was significantly changed in the second phase. The temporal and generational aspects of the device's behavior were no longer being entirely controlled by the dancer, but mostly by the device itself. That includes the use of various beats, with various tempos, with randomized playback time, and the tempo change of the played back beats. Also, regarding the visuals, the shuffling video effect was an action from the device's side. Therefore, they were affecting the dancer, on a temporal and generational level. Regarding the dancer's body, the way that the dancer utilized his/her body became intertwined with the device's behavior, in-depth, and layers. That matter became possible using the dependent mapping technic.

In the design of the device, the mapping system also had to be further developed. With regards to the dependent mapping system, there were changes made to make the device's behavior more complex and unpredictable. In order to do that, the amount of the movements of the dancer was measured and above a certain threshold, the device's behavior regarding one of the mapping parameters was changed. The amount of this threshold was randomized in a limited range so that it would not become predictable as well. Although the limitation implemented on the range was to stop the device from behaving too random. The parameter that was affected by this matter was the mix of the reverb effect. After a certain amount of movements being executed by the dancer, the device limited the ability of the dancer to implement the reverb effect on the played back beat. The duration of this limitation was limited for ten to twenty seconds, again on a random base. If the dancer moved more, this mode would have engaged sooner and if he moves less, this mode would have engaged later. As it can be observed, this change was implemented in the design, including both body and time categories in the design and randomization strategy, on a temporal level.

In the end, another mapping was added for muting the Piano sound to increase the convenience for the dancer, in order to trigger it on and off. It used acceleration input and triggered that function above a certain threshold. Also, since the Drum was removed, the clapping and foot-banging functionality were changed as well. This change is presented in the first iteration mappings section. The mapping techniques used in this system are diverse and inclusive. All three one-to-one, convergent, and divergent mapping techniques are used in this design.

#### *4.2.1.1 First iteration mappings*

Following, the mappings are listed:

- Clapping:
  - Starting the beats playback and Piano instrument
  - Changing the beat manually
  - Piano engagement (on and off)
- Right-hand movements:
  - Roll: Piano pitch
  - Yaw: Piano velocity (up to zero)
  - Acceleration (X-axis): Piano engagement (triggering on and off)
- Left-hand movements:
  - Roll: reverb and video delay mix
  - Acceleration (X-axis): reverb engagement and video delay (on and off) / reverb limitation (dependent mapping system)
- Foot-banging:
  - 1st bang: Starting the visuals and lifeline playback
  - 2nd bang: Stops the system sound completely

Following, a flowchart, demonstrating the design in this phase is presented in figure 4.8:

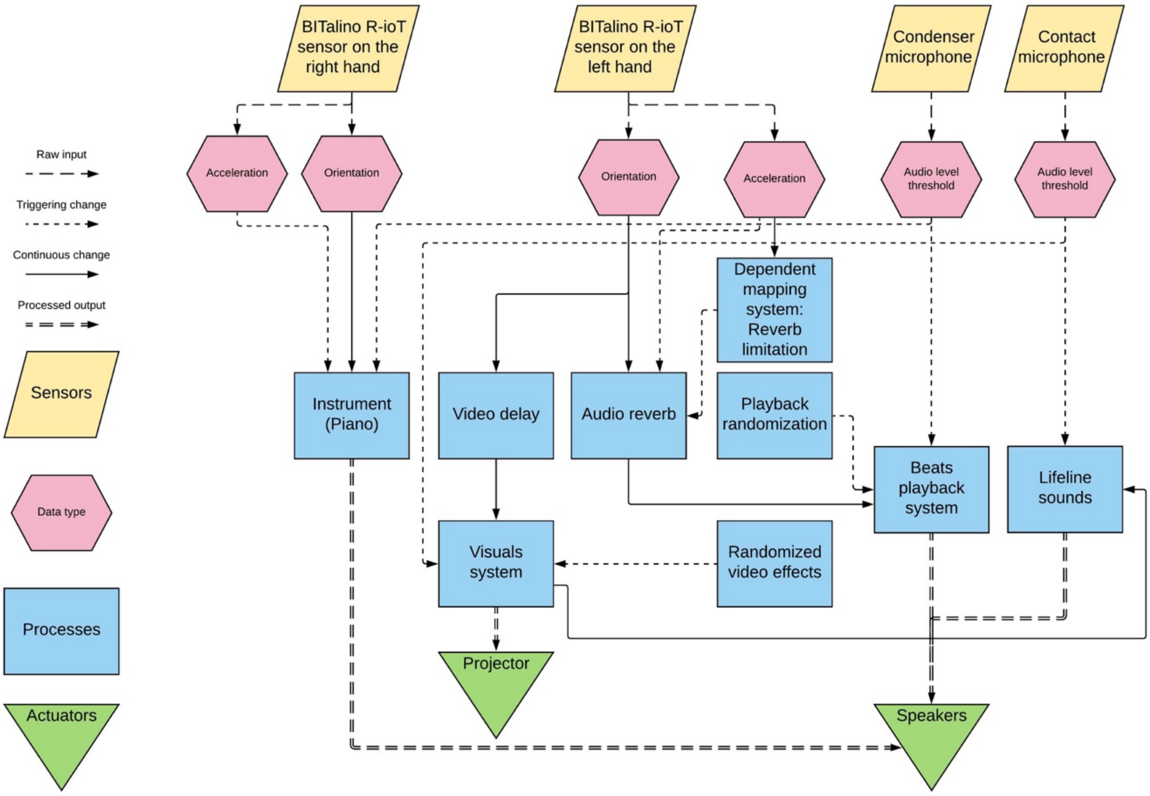


*Figure 4.8: First iteration's flowchart*

As it was discussed, there should have been several sessions conducted with the co-designer, to refine the prototype and design of the device, to reach an acceptable and optimal result, regarding the research argument. However, this iteration did not happen in the pre-decided timeframe (before the user evaluation process), due to the Coronavirus pandemic. But, during the evaluation process, the evaluator that I was working with, stated her opinion and answered the pre-made survey, and based on that I changed the design to some extent. That means, the evaluator turned into a co-designer as well. Therefore, the second iteration happened based on her input, to a limited extent. Also, with dedicating more time to the design process, another in-depth behavioral change, regarding the dependent mapping system, was implemented. Fortunately, after the second iteration, due to the new regulations that were implemented regarding having the access to the campus, I managed to have three more sessions with Abdullah (the co-designer) and finalized the iteration process and design. This procedure will be elaborated in the following section. Also, in those sessions, just for demonstrating the functionality of the first iteration design, I recorded a video of him, interacting with the system. It can be observed under the name of the "First iteration video" in the blog (see Appendix 5).

# 5 Evaluation of the practical work

The main plan for the evaluation was to involve several dancers in interacting with the system and using the survey method to collect their feedback. But, considering the Coronavirus crisis and the limitations imposed by the NTNU - which lead to not having access to the campus, in order to use it for the execution of the system - and not having access to the dancers, because of the imposed quarantine, there was no possibility to follow the preplanned procedure, for the evaluation.

However, my wife, Setareh Nejatian Kazemi, is an amateur contemporary dancer and I was able to have her engaged with the system, in a limited - home - environment. Therefore, I did not have access to projection and the visuals were being observed via a monitor, which was of course, not ideal. The sound was played back via a standard stereo speaker system which was acceptable. Also, the space available for her to dance was a little smaller than an optimal one (2 x 3 square meters), which was fine for testing the system. The auditory input system was set up and ran as it should. But it has to be considered, not having access to the video projection and a professional environment, may have affected the perception of the user in a negative way. This has to be mentioned that it might be problematic to have a close family member as an evaluator since he/she might be too sympathetic/positive. However, the circumstances did not allow many other options.

Regarding engagement with the system, there is a supplementary issue that can be raised and that is the initiation strategy, for the user. Two strategies can be mentioned, which both of them apply after the general introduction of the interactive system and its organs - sensors and actuators - their functions, and the way the user can communicate with it. Those strategies are:

- Supervised initiation: Presenting instructions for the user, so he/she gets to know the device's behavior
- Unsupervised initiation: Letting alone the dancer to explore the system and get familiarized with the device's behavior

In the first assessment, it may sound feasible to let the dancer explore the system by him/herself and work with it, in an unsupervised manner. The logic behind this strategy is that this approach may lead to a better quality in the exploratory procedure that he/she is going to experience and will affect the sensory experience of him/her - which is the focal matter in the dialogue between the dancer and the device - in a more suitable way. Thus, it can be deduced that intervening with the sensory relationship between the dancer and the device will affect the aesthetic relationship between them and is not suggested. However, in practice, the real circumstance may suggest the supervised approach since the other one may not be efficient and reasonable. This matter will be elaborated further in the text.

Working with Setareh, after introducing the system to her, I decided to let her engage with it without any further explanations to observe the outcomes of the abovementioned strategy. She is not a Hip-Hop dancer, but an amateur contemporary one. There are differences in the movement characteristics of those types of dances. Contemporary dance movements include more fluid and flowing movements, in comparison to the Hip-Hop dance which consists of usually sharper, quicker, and more isolated movements (Garcia, 2014). Thus, she engaged with the system with more fluid movements and in the beginning found it hard to communicate with it. Also, she was aware of space and equipment limitations that may affect the range and effectiveness of the device's behavior.

After a short amount of time - approximately five minutes - she got a hold of the basic mapping functions. Those include controlling the Piano and changing the beats. But after a while engaging with the system, I reckoned that regarding certain types of mappings, the chance that she could identify them was very slim. Those mappings were the ones that needed rapid accelerations in order to function. Because of the style of her dance, I deduced that she will not be able to notify them. That is a matter that could be probable regarding a Hip-Hop dancer as well. That is because the acceleration threshold that is defined for the mapping to be triggered is very high, so it would not interfere with the usual movements of the dancer. The mappings that consist of that are Piano, reverb, and the video delay engagement (on and off) ones. Therefore, it can be concluded that it is necessary to provide certain instructions for the dancer, so he/she can fully engage with the system and become able to interact with the device, with its full capability. However, having a limited supervised approach may be beneficial. That means, to not necessarily address the dependent mapping system, which is implemented in the system. Because it is a part of the device's behavior that is related to the creation of the sense of surprise.

As it was mentioned, there was a survey prepared for the users to evaluate the system based on their experience. This survey was conducted with a mixed approach and consisted of both using questionnaires with numerically rated items and open-ended questions. The numerically rated items were not optimal for such research, but they were used for the convenience of the users and to ease the process of eliciting the data (considering the possibility of a high number of evaluators). Also, the open-ended questions in the end balance out this matter. However, as aforementioned, it was not possible to have access to several users, and therefore I had only one user, filling out the survey. The survey was handed out to the user right after she engaged with the system, in the form of a digital text file and she answered the questions orally. Also, there was a question asked by her, regarding the term, dialogue, which was answered orally. Following the questions and answers that were registered by the user are presented in table 5.1:

*Table 5.1: Survey questions and given answers*

| On the scale of 1 to 10 (minimum - maximum), please answer the following questions: | Answer |
|---|---|
| 1- How much effort did it take you to cope with the device's behavior?<br><br>Coping, in a sense that you recognize the device's behavior with all its characteristics and embrace it, in the interaction. | 10 |
| 2- To what extent did you find yourself in control of the device, after coping with it? | 5 |
| 3- How much did you find the device predictable in the interaction? | 6 |
| 4- How much did you feel the sense of surprise, regarding the device's audio output? | 8 |
| 5- How much did you feel the sense of surprise, regarding the device's visual output? | N/A |
| 6- Were the challenges in the interaction frustrating or inviting for you?<br><br>The range between frustrating and inviting is 1 (very frustrating) to 10 (very inviting) | 9 |
| 7- To what extent did you feel a sense of dialogue between yourself and the device, in the system?<br><br>Dialogue, in a sense that both sides engaged in the interaction are being active towards each other and taking part in this common interaction. | 10 |

Analyzing the first question, the device and system design are ought to show an acceptable level of affordance, regarding the ability to communicate with the user. The device, being too easy or too hard, being coped with, is not an optimal result. Therefore, the optimal range is the mid-range between one to ten. As can be observed, it was hard for the dancer, as an amateur contemporary one, to cope with the device's behavior and she found this procedure challenging. This is not an optimal result. But I cannot rely on it, based on the proficiency of the dancer and relevance of her dance style.

Regarding question number two, it is about the matter of control, which leads to recognition of the active part of each side, in the interaction. It can be concluded that the device has managed to take a significant part, aesthetically in the interaction, almost as equal as the user.

It has to be mentioned that, regarding questions three, four, and five. I decided to ask, to some extent, the same question in different manners. Therefore, more compatible the numbers are, the more solid the answer would be. Here, the contradiction of the values in the answers would present the solidity of the answer. A low level of predictability, alongside, high level of the sense of surprise in the system, go together, and vice versa. Although the numbers regarding questions three and four are a little incompatible and the contradiction is not bold, still, the sense of surprise is more dominant in comparison to a predictable behavior from the device, which is a positive point.

Question number five evaluates the strategies used in the visuals for surprising the dancer. However, in this case of evaluation, because of the space that the system was tried in it, it was irrelevant.

Question number seven tries to assess the behavior of the device, to see if it has been successful in the creation of a balance between, it being challenging enough to not become entirely predictable, and still being rewarding in the cognition process, so the dancer would find it exciting to interact with it, and not become frustrated during this process. The answer states that the design has been successful in the creation of the later one.

Lastly, the device being successful in conveying the sense of surprise is an important issue. But it is a step towards the main objective of the research, and that is to convey a sense of dialogue via the use of surprise is the interaction, which is the subject of the last question. Despite the logical conclusion, it can be observed that, on an empirical level, the result is acceptable and it can be stated that the device has been successful to convey that sense.

Also, two generic open-ended questions that were asked at the end of the survey were:

- How did you find the device's behavior as an active opponent - not only a responsive one - in the interaction?
- What were the issues that you found inconvenient, about device affordances, regarding its behavior and communication with the user?

In respect to the first question, the user found the supervised initiation more convenient and feasible for the engagement with the system. She mentioned a sense of character in communication with the device and found the device's behavior strongly effective on her movements, to the extent that it disrupted her plans. That means in the process of planning her movements and overcoming the device, the device's behavior disrupted this procedure and claimed its part in the interaction.

Regarding the second question, she criticized the use of the Piano instrument in the system. She mentioned that:

> from my aesthetical judgment, I find the ongoing piano sound incompatible with the nature of Hip-Hop. It mostly raises a sense of classical or jazz music in me and I think the use of more relevant instruments could be beneficial for the system.

Although this may be reduced to a personal opinion, I found it relevant and chose to implement a change in choosing the instrument or the sonic output, based on its relevance to Hip-Hop music.

## 5.1 Continuation of the iteration phase

As it was mentioned, the process of refinement in the iteration phase, required several sessions with the co-designer/dancer. But this could not happen as scheduled, because of the Coronavirus situation. Therefore, the second iteration happened after the evaluation process, by considering the input of the evaluator. But after that, due to the changes in regulations, I had access to the co-designer and the third and fourth (final) iterations happened afterward with his collaboration. It needs to be stated that there was a limit to this iteration and it was defined by the judgment of the designer and co-designer. Further, the rest of the iterations will be elaborated.

### 5.1.1 Second iteration

Regarding the feedback of the evaluator about the irrelevance of the Piano, by doing more research on Hip-Hop music, it could be observed that:

> music among the rappers can be perceived apart from a 'being in the world'. They say that they sing the reality in which they live and this narrative is permeated by feelings, as music surges from the experience that they narrate (Souza & Montardo, 2011).

Thus, it can be deduced that the core element in this music is its text. Driven by that fact, I found it interesting to replace the Piano with playback of various lectures, that were relevant to the subject of the performance, and use the Piano mapping parameters - Yaw and Roll and hand's acceleration - to manipulate the played back lecture. Therefore, the synthesization process was removed from the patch and its audio-related functions became limited to implementing effects on lectures and lifeline sounds.

After the implementation of that idea, the following changes were made. Roll value affected the speed of the playback - which caused a pitch shift effect as well - and Yaw value affected the level of it. Also, the acceleration was used for triggering it on and off. Another temporal manipulation was implemented in the patch as well, which was a distortion effect on the lectures. The mix of the distortion was based on the amount of the movements of the respected hand - in this case, the right hand - and as the amount rose, the distortion mix rose as well. The reason for choosing the distortion effect was to intensify the affection of the lecture and dramatize the feelings, aroused by it. Implementing the randomness strategy, there was a random threshold number defined for the amount of the movements, that by surpassing it, the amount was reset, and therefore the mix of the distortion went back to zero and the circle of adding the distortion started again. This randomness was happening both on a generational (i.e., its dependence on the amount of the dancer's movements) and temporal (i.e., the amount of the movements defined the time that it reset itself) level. The reverb effect was not affecting the beats anymore. However, the lectures, before being sent to the main device output, were sent to the reverb effect and even with having them muted, if the reverb was turned on and its mix was high enough, they could be heard in an atmospheric way, serving the affectional aspects of the device on the performer. It also maintained the consistency of the lectures and enhanced the sonic texture of the output.

#### *5.1.1.1 Second iteration mappings*

Following, the mappings can be observed. It has to be mentioned that these mappings will remain consistent in the next iterations as well.

- Clapping:
  - Starting the beats and lectures playback
  - Changing the beat manually
  - Lectures engagement (on and off)

- Right-hand movements:
    - Roll: Lectures speed
    - Yaw: Lectures level
    - Acceleration (X-axis): Lectures engagement (triggering on and off) / distortion amount (adding up during time)
- Left-hand movements:
    - Roll: reverb and video delay mix
    - Acceleration (X-axis): reverb engagement and video delay (on and off) / reverb limitation (dependent mapping system)
- Foot-banging:
    - 1st bang: Starting the visuals and lifeline playback
    - 2nd bang: Stops the system sound completely

Following, in figure 5.1, the design flow chart is demonstrated. This flowchart can be applied to the other iterations as well.

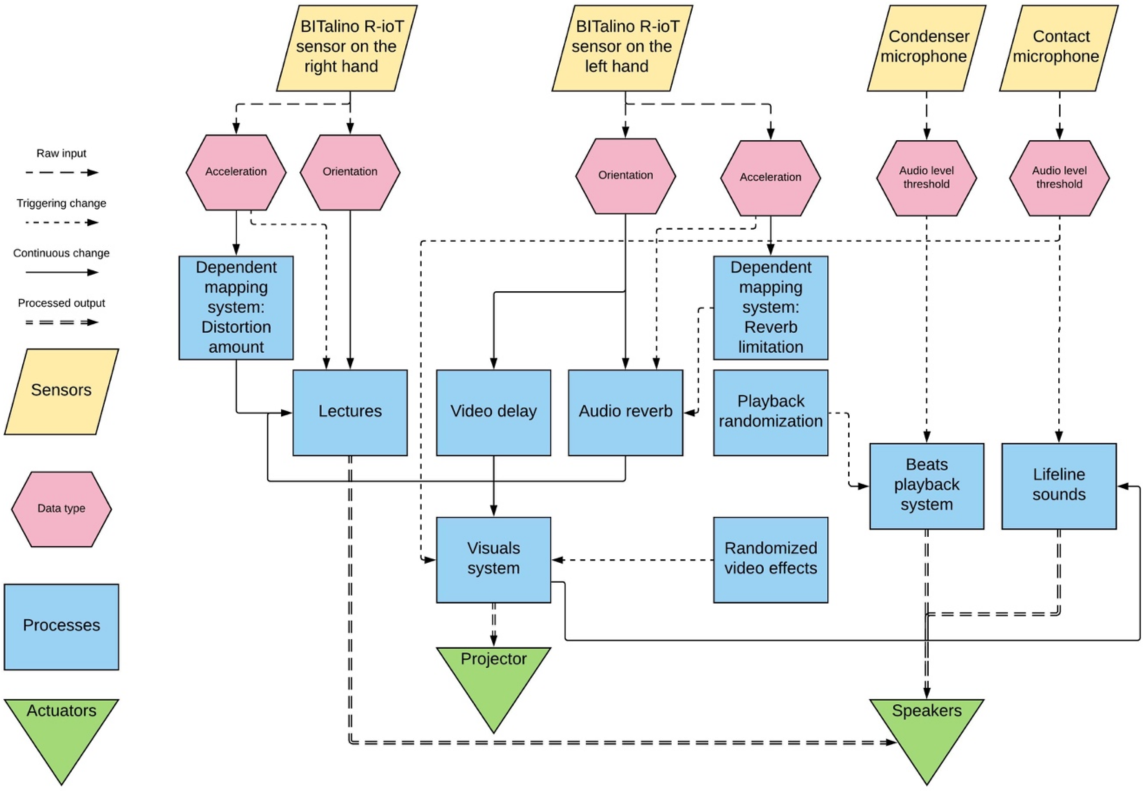


*Figure 5.1: Second iteration's flowchart*

From a logical perspective, the changes were ought to lead to a more perspective coherence in the system design. After implementing the changes, the evaluator tried the system again and she briefly mentioned that: 'although it has made the device's behavior more complicated, the way that elements work with each other make more sense now'. However, this feedback partly is based on the evaluator's suggestion since she acted as a co-designer as well and could be biased. Also, her being a family member of the researcher, may have negative effects on her evaluation since it might have become biased. I recorded a video, just for the demonstration purpose, which can be found in the blog, by the name of "Second iteration video" (see Appendix 6).

### 5.1.2 Third iteration

In the third session with Abdullah, as before, during conducting a relationship between himself and the device, he tried to define his part in the interaction. He mentioned that the independent behavior (i.e., actions) of the device played a significant role in possessing its part in the interaction. That means these independent actions were stopping him, from possessing all the parts in the interaction and lead to the creation of a dynamic aesthetic relationship. Needless to say, those actions were conducted, utilizing the defined strategies that were ought to create the sense of surprise - randomness and dependent mapping system.

Another important observation was, the design of the device showed enough flexibility in a way that he could utilize it, in regards to his/her own movements. For instance, regarding the acceleration - which was used for triggering on and off the device's functions - the dancer could adjust his/her move to the predefined respected axis of the accelerometer, and trigger the function with a customized move of his/her. It can be observed in the video recording that is provided, further in the text.

Another important matter that was pointed out, was the engagement of the dancer with the device. This engagement is based on the outputs of the device. That means if the audio or visual materials are inviting enough for the dancer, the chance of him/her getting engaged with it rises. He mentioned a simple, but important matter and that was: 'in order to become surprised by the changes in the device's behavior, first you have to be engaged with it'. Thus, regarding that matter, he suggested increasing the number of beats and choosing various beats, from various Hip-Hop sub-genres to make the device's output more comprehensive and appealing for a wider variety of Hip-Hop dancers. Also, he mentioned that it may increase the chance of the dancer to become surprised by hearing a contrast between the beats the device is playing back to him/her.

The video recording of Abdullah, trying to interact with the system in this iteration phase, can be found in the blog, under the name of "Third iteration video" (see Appendix 7). However, due to a technical problem (i.e., computer overheating[8]), I had to turn off the video pixelation process.

### 5.1.3 Fourth (final) iteration

In the final iteration, the number of beats was increased to five, and the lectures to six. That provided a wider verity in the device output, for the dancer to engage with it, and Abdullah admitted that matter as well. It could be observed that implementing a wider variety of beats in the patch, increased the chance of him becoming engaged with the device and also, made it more possible for him to become surprised, by hearing a contrast between the randomly played back beats. That was also confirmed by Abdullah.

He also tried to interact with the visuals and lectures and adjust his movements regarding them. Those, plus his engagement with beats and partly the way the changes in the device's behavior affect his perception, can be observed in the video available in the blog, by the name

[8] "When a computer or electronic device generates more heat than it is designed to handle, it is said to be overheating. A computer that overheats may shut down without warning to prevent permanent damage to its hardware, especially the processor" (Computer Hope, 2019).

of “Fourth (final) iteration video” (see Appendix 8). The mentioned affection and the surprise created by the device, in particular, can be observed at 01:30, until the end of the video. The surprise that is supposed to allow the device to take its part in the interaction and create the sense of dialogue in the dance. Again, due to computer overheating, I had to turn off the video pixelation process.

However, regarding the evaluation, this cannot be denied that the more feedback the system receives, the more promising the results would be and the process of future development may be more prospective, both from the system design and aesthetical judgment perspectives. That can be the result of receiving feedback from various dancers, with various dance styles - within Hip-Hop style - cognitive abilities, and technical proficiencies.

# 6 Future possibilities regarding the practical work

Certainly, the conceptual and technical aspects of practical work are intertwined. That means, to implement a technical change or design, there should be a concept that supports it. In the theoretical framework section, the questions *what*, *when*, *why*, and *where* are ones that associate with the concept expectation. In less complicated settings, *what* and *when* are the most relevant question. However, when it gets to more complicated setups, *why* and *when* engage. For instance, in the thesis practical work, regarding the dependent mapping system, *why* and *when* are the logical questions that may occur to the user. Based on those questions, the spatial and temporal and trajectorial aspects of the practical work (i.e., space, time, and body) could be the areas of focus regarding the future possible enhancements and changes.

One of the main suggestions regarding the future possible works is the use of a multi-channel playback system and randomizing the sound output, between various speakers. This can include the routing of the dry and/or effected sounds. This possibility will bold out the question *where* and provides a richer texture for the dancer, to build his/her expectation on it and also will expand the ability of the device to act towards the dancer, in the aesthetic relationship between themselves. The other suggestion is to enhance the dependent mapping system, both in-depth and expansion.

Also, another suggestion is to include machine learning. Machine learning 'works by developing procedures that take input data and then by applying statistical analysis on the data, it predicts an output' (Sehrawat & Gill, 2020, p. 12). This way the dancer's movements can be analyzed and the surprising attitude of system may change, based on each dancer's individual movements. This requires more strategies in creation of the sense of surprise as well.

Having mentioned the suggested possibilities, I shall conclude the theoretical argument, the implementation of it in the procedure of the design of the practical work, and the evaluation process, in the conclusion section.

# 7 Conclusion

In this thesis, the research objective was to define how and to what degree can an interactive dance performance with a Hip-Hop dancer, using absolute orientation sensors and auditory input, convey a human-computer interactive dialogue through surprise and movement-sound mappings.

The key points to the work were to present that the creation of a sense of surprise in the dancer during his/her interaction with the device, by the device's behavior, in an interactive dance system, disrupts the dominance of the dancer in their interaction. It was stated that the dancer and the device, both take parts in this common interaction and the process of taking parts in this interaction has an aesthetical nature. Thus, the goal was to state that, allowing the device to possess its parts in this interaction, by the use of surprise, will cease the dancer to take over in their interaction. This was supposed to lead to a condition that the dancer senses the ongoing procedure of taking parts by himself and the device, which is referred to as dialogue, between him/herself and the device.

The answer to that question, a theoretical framework was defined, and based on those, a design strategy was conducted to create execute the mentioned proposal. This design strategy was put into practice, by the help of a dancer/co-designer, in order to be tested and fortitude the theoretical argument. However, the practical work needed to be used by various dancers, so they could evaluate the prominence of the presented argument in practice. But, considering the Coronavirus pandemic, this did not become possible. Although there was access to one evaluator and the feedback received from her (which could be positively biased, based on her, being a relative to the researcher), plus having dialogues with the co-designer and observing his state during the iteration process, in the interaction with the device, a rough evaluation became possible.

Based on those, on a limited scale, it can be stated that by using a balanced amount of randomness and increase of the dependent mapping system, the device can become able to affect the dancer's perception of its behavior and create a sense of surprise, and followed by that, a sense of dialogue in the interaction, for the dancer. However, this evaluation is certainly not optimal based on the aforementioned reasons.

It can be stated that the creation of the sense of dialogue in the interactive dance systems, may be beneficial to create a more aesthetic interaction and to avoid the device to act submissively towards the dancer so that the dancer would use his body as an instrument to create and adjust device's outputs. In such aesthetic interaction, the dancer would sense an ongoing dialogue with the device, in the interactive dance system, which makes the interaction challenging and dynamic during the respected performances, or installations. This approach may lead to creation of new potentials in the interactive dance systems, expanding more on technical and philosophical aspects of it

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## Appendices

The zip file accompanying this thesis includes the following material:
**Appendix 1:** Audio file, “Transition between above the surface and underwater sound”
**Appendix 2:** Audio file, “Piano sonification”
**Appendix 3:** Audio file, “Drum sonification”
**Appendix 4:** Audio file, “Initial design audio output”
**Appendix 5:** Video file, “First iteration video”
**Appendix 6:** Video file, “Second iteration video”
**Appendix 7:** Video file, “Third iteration video”
**Appendix 8:** Video file, “Fourth (final) iteration video’

## Appendix 1

### Description:

An audio recording of the lifeline in the practical work.

### Filename:

Transition between above the surface and underwater sound.mp3

## Appendix 2

### Description:

An audio recording of the Piano instrument, available in the initial design and first iteration of the practical work.

### Filename:

Piano sonification.mp3

# Appendix 3

## Description:

An audio recording of the Drum instrument, available in the initial design of the practical work.

## Filename:

Drum sonification.mp3

# Appendix 4

## Description:

An audio recording of the practical work’s initial design audio output.

## Filename:

Initial design audio output.mp3

## Appendix 5

### Description:

A video recording of the practical work's first iteration, at NTNU campus, the portal room for the program Master of Music, Communication, and Technology. Performed by the dancer/co-designer, Abdullah Ghazanfar.

### Filename:

First iteration video.mp4

## Appendix 6

### Description:

A video recording of the practical work’s second iteration, at NTNU campus, the portal room for the program Master of Music, Communication, and Technology. Performed by the researcher.

### Filename:

Second iteration video.mp4

## Appendix 7

### Description:

A video recording of the practical work's third iteration, at NTNU campus, the portal room for the program Master of Music, Communication, and Technology. Performed by the dancer/co-designer, Abdullah Ghazanfar.

### Filename:

Third iteration video.mp4

## Appendix 8

### Description:

A video recording of the practical work's fourth (final) iteration, at NTNU campus, the portal room for the program Master of Music, Communication, and Technology. Performed by the dancer/co-designer, Abdullah Ghazanfar.

### Filename:

Fourth iteration video.mp4

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