# EnActor: A Blueprint for a Whole Body Interaction Design Software

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## ABSTRACT

Through a series of collaborative research projects using Orient, a wireless, inertial sensor-based motion capture system, I have studied the requirements of musicians, dancers, performers and choreographers and identified various design strategies for the realization of Whole Body Interactive (WBI) performance systems. The acquired experience and knowledge led to the design and development of EnActor, prototype Whole Body Interaction Design software. The software has been realized as a collection of modules that were proved valuable for the design of interactive performance systems that are directly controlled by the body.

This paper presents EnActor's layout as a blueprint for the design and development of more sophisticated descendants. Complete video archive of my research projects in WBI performance systems at: http://www.inter-axions.com

## Keywords

Whole Body Interaction, Motion Capture, Interactive Performance Systems, Interaction Design, Software Prototype,

## 1. INTRODUCTION

The appreciation of the whole body as a medium for exploring interactivity with digital media emerged with advances of technology that enabled the capture, analysis and communication of physical and physiological data from a user to a computer system. Whole Body Interaction (WBI) is a technologically-driven experience that engages the whole body to a reciprocal relation with digital systems and has to be analyzed and further understood through the development of new experiences and additional knowledge. As a term, WBI was first introduced at the 24th International Conference on Computer Graphics, (Siggraph,1997) in order to describe the design approach taken by Fels (1997) for the installation Lamascope: an interactive kaleidoscope.[1]

In recent years, the term has been broadly discussed in the context of HCI, as the basis for the formation ofa new framework in interaction design. Most notable in this discussion are the contributions of David England who organized a series of workshops in WBI as part of the ACM International Computer Human Interaction conference (CHI).


*NIME'12*, May 21-23, 2012, University of Michigan, Ann Arbor.


A WBI scheme in a performance arts context, could operate through the sensing of either the physical or physiological data of the body or both, but primarily based on the artistic concept of each performance. This paper discusses a software framework for the realization of WBI performance systems focused on physical, movement-position data.

Motion capture technologies are the most appropriate for musicians, dancers and choreographers to comprehensively study interactivity, since they can provide fundamental, detailed and reliable data about the body's posture, shape, movement dynamics and position in space.

DeLahunta observes that choreographers have been especially reticent to use live performance technologies, like optical motion capture systems, because of their technical complexity and demanding infrastructure.[2] Despite their limitations, since the mid-1990s, researchers, choreographers, musicians and technologists, have explored the artistic potential of optical motion capture systems in real-time operation and set a number of important precedents. Of major importance is the contribution of Bevilacqua and Dobrian. Using an optical motion capture system (Vicon8) they explored the synthesis of interactive sound directly from a dancer's movement using full-body motion capture data. [3][4].

A high volume of related research and artistic work, especially in the dance context, has been carried out at the Herberger Institute at Arizona State University. In a dedicated motion capture lab called Motion-e, a permanently installed optical motion capture system was customized with various technologies to increase its reliability and bypass the additional challenges of its real-time use on the performance stage. [5]

While optical motion capture systems have been most frequently used in early explorations, there are a number of limitations for their use on the performance stage including the requirement for a uniform with visible LED or reflective markers, light dependencies, occlusion and a highly demanding infrastructure. Therefore, new technologies are required for extensive studies in this field. Current advances in wireless inertial motion capture solutions are very promising for delivering this coherent technological framework and enabling creative explorations of interactivity in real-time performances.

Using *Orient*, the first fully-wireless, full-body inertial sensor motion capture system, developed by the Research Consortium in Speckled Computing at the University of Edinburgh, I investigated the development of a design framework for the realization of WBI performances in an artistic context. [6][7][8] Fifteen Orient devices provide a full-body motion capture. Figure 1.

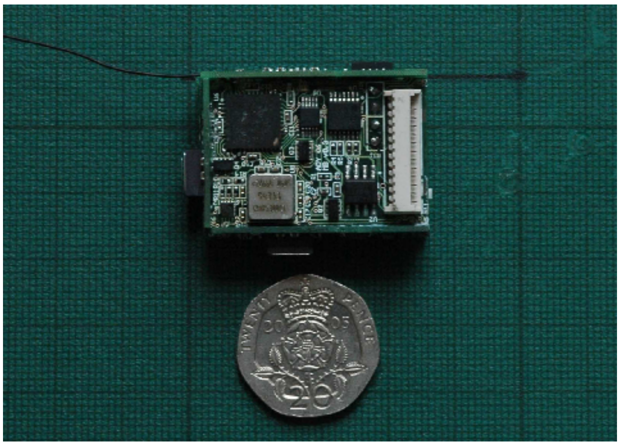

**Figure 1. A wireless Orient sensor**

Following the advances in commercial inertial motion capture systems, Skogstad and Quay have also been working on the development of a music and dance performance system based on the XSens motion capture bodysuit MVN Biomech.[9] [10]

Acknowledging the growing interest in the design of body-based interactive performances, musical instruments and other gestural controlled applications, it is necessary to design and implement additional software platforms that can accommodate the needs of artists, users and whole body interaction designers.

# 2. ENACTOR'S DESIGN BACKGROUND

Various basic concepts extracted from my preliminary practical research explorations have informed the design of EnActor.

## 2.1 Types of WBI Performance systems

Adopting the understanding of interactivity as a property between systems, proposed by Dubberly et al. (2009), I have identified three basic types of interactive performance systems: *methodical*, *empirical* and *dialectic*. [11] The interactive mechanism of a methodic system has fixed properties and the performer can be trained to operate and learn it, similarly to a musical instrument. Empirical interactive performance systems adjust their goals and share the control of their synthesis processes with the performer, who is trained to interact with the system through experience, similarly to performing a musical score, dancing a choreographic sequence, or navigating within an interactive space. Finally, dialectic systems employ artificial intelligent processes, able to interpret the performer's actions as feedback prior to responding. A WBI performance system can follow one of these generic interaction design paradigms or a combination of all of these in order to address more complex scenarios and specific artistic concepts.

EnActor in its current state can only be used to design methodical and empirical WBI performance systems. To reach the next level, the software will need to provide a wide range of tools for the development of dialectic systems.

## 2.2 Kinetic and Spatial Interactions

Kinetic-based interactions create the synthesized sound directly based on the dynamics of movement, as well as various angles and relative distances between the joints of the body. These can follow a wide range of mapping techniques that correspond best to the artistic requirements of a piece.

Spatial interactions are more complex as they require much higher precision by the motion capture system and can be very challenging to implement. Optical motion capture systems measure the positions of the joints in order to further extract their rotations, therefore have higher accuracy for the design of spatial interactions. In contrast, inertial sensor-based solutions measure rotations in order to calculate their positions and therefore have more accuracy when designing kinetic-based interactions. The scenarios and algorithms that can follow the design of these interactions are similar to video game and Virtual Reality (VR) techniques, such as the collision detection processes.

Using additional technology for position tracking, such as a ceiling camera, a step tracking algorithm or RF tagging, it is possible to extend an inertial motion capture system to represent a fully interactive performance stage. This enables the tracking of performers "at multiple temporal and spatial levels", as proposed by Sundaram et al. (2006). [12]

It is important to mention that in order to design successful spatial interactions an exact virtual body model that is analogous to the actual physical body of the performer needs to be constructed.

# 3. ENACTOR'S BLUEPRINT DIAGRAM

EnActor is a prototype WBI Design software platform that is able to assist the exploration of a wide range of scenarios. It has been designed as a core-engine with a collection of interconnected modules and various additional extension algorithms, all implemented in Max/MSP.

EnActor's design layout consists of eight basic layers: the motion tracking and analysis; the core-engine; the whole body control panel; the preset manger; the extension modules; the sound composition; the digital musical instruments and the speaker's mapping. Each layer is described in further detail in the following sections and EnActor's blueprint diagram can be seen in the Appendix.

## 3.1 The Hit-Frame

Thinking of a musician hitting a drum or plucking a guitar, the sound emerges at the end of the performed action. Similarly, when using a percussive or string metaphor to sonify or accompany an action, the responsive sound should begin just as the movement ends. In contrast, this association is weaker with sound responses that reference a wind instrument or a drone effect. With this type of response, the sound should start from the beginning of the movement, sustain and decay, following the dynamics of the movement for the duration of the entire action. Therefore, a responsive hit detection mechanism should be able to optionally initiate the sound at the beginning or the end of an action.

A hit frame can correspond to a specific event or a note on a virtual instrument, or it can trigger a sound on a sampler based on certain predefined parameters. Figure 2. With pattern-following paradigms, the responsive system can associate the produced hits correspond to events or musical notes that are produced following a predetermined or an evolving pattern.

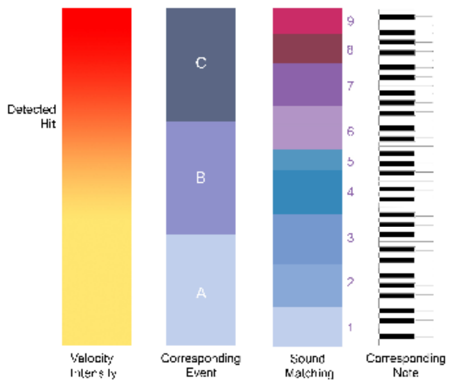


**Figure 2. Matching the energy/intensity of a detected hit to various corresponding events**

## 3.2 Motion Analysis

The motion analysis layer consists of algorithms that analyze and distribute the body and movement data to all modules of EnActor, after they have been constructed by the motion capture system. These include the position and rotation of each body joint and its velocity vector. The position is reported in both the static and personal motion capture cubes that were previously described. Rotations are provided in both quaternions and Euler angles, while velocity is provided as a three axis vector plus its magnitude.

## 3.3 The Core-Engine

The core engine is based on the analysis of the velocity vector of any part of the body and has two basic functions: to identify and organize the produced hit-frames and to adjust the intensity of the system's responses. The following describe the engine's basic functions. Figure 3 shows EnAcor's core-engine GUI.

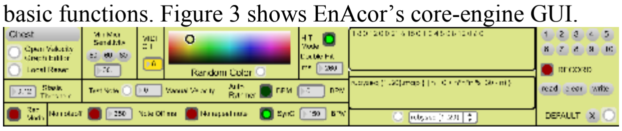


**Figure 3. The control panel of EnActor's core-engine**

The engine begins with the *normalization* of the velocity magnitude, either in a *dynamic* or a *static* mode. In static mode the maxima of velocity is set or obtained through a calibration process, while in dynamic mode the algorithm periodically measures the performer's maximum and mean velocity. The static mode is primarily used for designing methodic systems while the dynamic mode leads to an adaptive, empirical system.

Setting an *activity threshold,* as the minimum amount of activity needed to trigger a response, is required to define a range of low-motion, as stasis, where the system is put on hold. This can be independently set or linked to the normalization process, as a percentage of the overall intensity dynamic range. The detection of stasis can be additionally used to trigger other modules of the system, such as the posture recognition.

*Data filtering* is optional in order to create a smoother input, but since it contains time related functions, it is often used to the design of an empirical system's responsive character.

*Reshaping* the velocity data leads to a new intensity distribution with a desired effect. This can be done by selecting one of the predefined functions built into EnActor, such as an exponential one, or through defining a new specific mathematical formula. Figure 4 shows how the incoming velocity data can be re-shaped to produce much higher accents with the use of an exponential distribution.

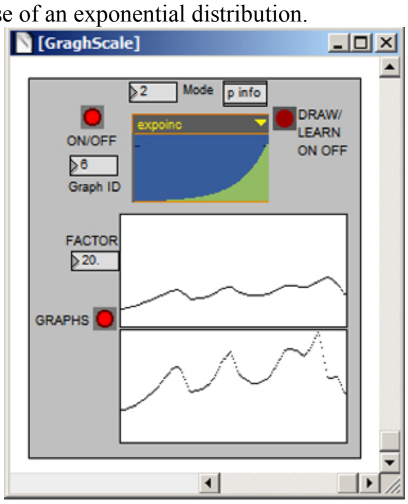


**Figure 4. Velocity data re-shaping following an exponential distribution**

This process can drastically alter the response to an action or be used to fine-tune the resulting sound. Taken to the extreme, we can even inverse the incoming data so that gross movements create subtle responses, while fine movements have intense responses.

Monitoring the velocity vector of a limb can provide additional information regarding the orientation of the movement and further classify a hit, for example detecting whether a hand created a hit while rotating or moving up, down, left, right, back or forth.

Constant orientation and velocity measurements reported for each part of the body, can be assigned to control continuous features of the sound, such as its playback speed, reverberation or filtering. This is especially effective when the produced sound is designed with reference to a wind instrument or a drone effect, as opposed to a percussive or a string sound.

By coding a mathematical formula or by simply providing the structure of a musical phrase in midi notes or numerical sequences, the detected hits can be organized to follow a specific musical pattern, while optionally syncing with a master clock that can provide the tempo. If this option is excluded, the intensity of the perceived hit will correspond to an arrangement of associated sound, events or midi notes as discussed earlier. (Figure 2). When designing pattern based interactions, the master clock can drive many other compositional subroutines, each one linked to a particular instance of the core-engine under the same tempo, or a subdivision of it. A time adjustment algorithm can further offer the coherence of the rhythm and the perception of its measure. This internal mechanism can assist the performer by either leaving a produced hit to generate sound instantly, or slightly delaying it in order to create a coherent rhythmical structure. This process ensures that each of the body's produced hits can be accurately registered within the defined rhythmical pattern and its time signature. The accuracy of the algorithm could be additionally adjusted to create a humanizing effect and avoid a quantized mechanical feeling.

EnActor uses a mechanism for assigning control data from the core-engines and the other modules to the sound synthesis modules using OSC.

## 3.4 The Whole Body Control Panel

Each part of the body is linked with a dedicated instance of the core-engine that can be easily accessed and adjusted from the Whole Body Control Panel. Based on the previously described components of the core engine, with particular adjustments, a wide variety of responsive scenarios can be programmed independently for each limb. The overall WBI system can be extremely versatile, and depending on the application and the design approach taken, it can lead to a methodical or an empirical system.

## 3.5 The Preset Manager

The preset manager is analogous to a page of a compositional score or a complete interaction idea, a WBI sketch. All of the programmed settings, for mapping activity data to the desired responses, including all described rules and mapping configurations, are stored in the preset manager. The presets that are designed for a specific application can be recalled automatically (time or pattern-based scenarios) or manually (state-based scenarios) during a performance.

## 3.6 EnActor's Extension Modules

### *3.6.1 Posture Recognition and Classification*

A body posture can function as a distinct moment for a choreographer, a composer and a performer and can be easily recognized by both the audience and the digital interactive system. Through data analysis and the implementation of simple recognition algorithms, a body posture can be learned, identified and recalled by EnActor. It can then be used to trigger a specific event or change the settings and mappings of the interactive system to a desired preset arrangement. This module can additionally instantly categorize the body's posture, into the following categories, based primarily on the position of the spine as in: a deep bend, a gamma position, a back-bend, a spine twist, a standing pose, leaning forward, and lying down.

### *3.6.2 Gesture Recognition*

Although gesture recognition was never practically applied to any of my research projects or live performances, the main concept can be helpful in various WBI interaction scenarios. Specifically detected gestures can be associated with the progression of a composition, the activation of an event or the recall of a preset. If it is more precisely used, gesture recognition can be employed for dance or music training applications. For a proof of concept, I tested the *Gesture Follower* algorithm implemented by the Institut de Recherche et Coordination Acoustique/Musique (IRCAM) and distributed under the FTM extension library for Max/MSP. [13]

### *3.6.3 Surround Sound Control*

Surround sound control with the body is often an interesting addition that can strengthen the link between gesture and sound. Indicating that the performer is in control of the projection sound source creates an additional layer of interactivity that can be immersive for the performer and also easily perceived by the audience. Depending on the setting and the brief, the sound panning can be done through simple faders or more sophisticated algorithms for surround control of sound, such as ambisonics.

### *3.6.4 Spatial Interactions and Orientation*

This extension module can be used for the design of spatial-based interactions. It is a collection of algorithms for the description of virtual 2D and 3D shapes, areas and volumes around the performer, and of collision detection.

The orientation of the performer in space is a rather abstract idea, since every part of the body has its own unique orientation, but it can provide a powerful tool for designing spatial interactions and controlling surround sound with the body. The parts of the body that I have found to be most useful for providing orientation information are: the hand, where the performer is pointing at; the head, where the performer is looking at; the hips, where the performer is standing towards, and the chest, where the performer is facing at.

## 4. CONCLUSION

EnActor is a prototype software platform for the design of WBI performance systems, and can serve as a blueprint for the development of other dedicated software for the exploration of body-based artistic projects and applications. Its modular nature and the simplicity of its core-engine illustrate the basic functions for the design of kinetic and spatial-based interactions within the paradigms of methodic and empirical interactive performance systems. Dialectic systems that are based on Artificial Intelligence algorithms can be further explored through the development of additional extensions for EnActor.

EnActor has been used and tested in the design of three WBI performance systems: Duende, that was designed in the traditional dance context of Flamenco; Hiroshima, a complete compositional driven system for a sonic theatrical piece based on various music composition ideas and a detailed performance score; and EnYoga, a system for the sonification of Yoga. [14]

Overall, it seems that we are moving towards an interactive performance media holism where disciplines such as dance, theatre, music, performance art, cinema, virtual reality and video game design can meet in a common ground that a reliable, unencumbered real-time motion capture technology will soon enable. Therefore, there is a growing need for the development of robust tools that can assist the design of WBI applications that can push the boundaries of storytelling further.

These explorations should be in direct dialogue with the traditional and contemporary artistic practices, aim to seamlessly transfer the embodied skills of performers in a WBI digital setting and concern ways to communicate these emerging immersive experiences with a broader audience.

## 5. ACKNOWLEDGMENTS

This work has been funded by the Arts and Humanities Research Counsil, AHRC – UK. Special thanks to all my collaborators and the Research Consortium in Speckled Computing, University of Edinburgh.

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# 7. Appendix

## EnActor's Blueprint – Design Diagram