esencia: A Case Study on Reinterpreting an Interactive Art and Science Installation Based on a Real-Time Atomic Physics Engine

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Abstract

The complex nature of interactive art challenges existing methods of art preservation. While technology offers almost unlimited possibilities for this genre of art, it also introduces significant risks of hardware and software obsolescence. This, in turn, often leads to an irreparable loss. This paper presents a case study on reinterpretation as a preservation strategy for interactive art. We worked with *danceroom Spectroscopy*, an award-winning interactive art and science installation facing the risks mentioned above. We outline the dependencies of *danceroom Spectroscopy* and their update to new software framework and hardware, including depth video processing, and particle simulation with GPU acceleration that resulted in system's performance improvement. We also highlight the importance of proactive preservation techniques for digital interactive artworks, and the challenges of working with complex computational processes and custom hardware.

CCS Concepts

• **Applied computing** → **Media arts**; • **Human-centered computing** → *Graphics input devices*; Scientific visualization; • **Information systems** → *Digital libraries and archives.*

Keywords

Interactive art, preservation, reinterpretation, art and science, installation, depth sensors

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1 Introduction

In this paper, we present a case study on the preservation of an award-winning interactive art and science installation called *danceroom Spectroscopy* (*dS*) which was developed from 2011 to 2015, and which is at risk of disappearing from hardware and software obsolescence. With a fundamental goal to make the artwork accessible for future installations, we chose reinterpretation as the preservation strategy to: a) preserve the aesthetic experience of the artwork; b) update the software and hardware dependencies in open source fashion, facilitating further remixes; and c) use artistic freedom to expand the original piece. *esencia*, our open source [4] *dS* reinterpretation, was developed using standard artistic software tools (openFrameworks), and new available hardware (Orbbec Femto, the closest to a Kinect successor).

This paper describes: a) what *danceroom Spectroscopy* is, and why it is important to preserve it; b) why we choose reinterpretation as the preservation strategy; c) the architecture of *esencia*, and how each component works; and d) reflections on the derived adaptations and the overall experiences aroused during this project.

For this project, we had access to the original artwork's hardware and software in the *Intangible Realities Laboratory* (IRL) at the University of Santiago de Compostela, likely the only place where the installation is still available. The IRL carries out research at the immersive frontiers of scientific, aesthetic, computational, and technological practice. For example, the IRL creates tools for physicists, chemists, and biologist to visualize and interact with real-time molecular simulations in VR. They have recently adapted this technology to create VR experiences for supporting neuroscientific studies aimed at understanding perception and improving mental health.

2 *danceroom Spectroscopy*

Art and science represent two fundamental human paradigms for exploring and understanding reality. While they employ distinct methodologies and frameworks, they both enrich our understanding of the world in complementary ways [40]. Digital art, by its very nature, creates a fertile intersection of artistic and scientific practices. That's why early digital art was first explored at technology institutes like the Bell Labs in the 60s [45]. This practice flourished particularly during the 2000s and 2010s, facilitated by advancements in accessible computing technology and institutional support from established organizations like the MIT Media Lab and CERN's Arts at CERN program, alongside the emergence and consolidation of new-media-art institutions.

danceroom spectroscopy was born as "an interactive visual art installation and performance system driven by rigorous algorithms commonly used to simulate and analyze nanoscale atomic dynamics" [42]. It was conceived by artists and scientists, motivated by the desire to create "an artistic installation that enables humans to have a real-time immersive experience of 'becoming' energy landscapes" [42]. "Energy landscape" is the metaphor used by chemist, physicist, and biologist to describe a topological map of a system's potential energy, which guides atomic configurations into structures like molecules. In that regard, *ds* "interprets people's movements as perturbations on a virtual energy landscape" [25] by placing their image into a system where simulated atoms move according to algorithms that govern "the dynamics of molecular systems in both classical and quantum frameworks" [25]. The simulation is rendered and displayed on a large projection screen. Custom hardware and software were built to handle the high-computational load required to achieve smooth real-time atomic simulations, to render aesthetic graphic representations, and to perform sonification analysis [21].

Beyond their technological components, interactive artworks often emerge from the collaboration of multiple artists, technicians, performers, and audiences [17]. Furthermore, these artworks can create an environment and possibilities for co-participation between different people that can give rise to derivative projects. *danceroom Spectroscopy* was the type of project that created a space for new ideas [21]. In 2012 *Hidden Fields* (HF), a dance performance using *dS* was developed. It brought together artists, musicians, and performers to perform using *dS* in a 50-minute, narrative-based, contemporary dance performance. From 2012 to 2016 *dS* and *HF* were presented in more than 40 venues, such as the Zentrum für Kunst und Medien, London's Barbican Arts Centre, and the Stanford Art Gallery. It received an Honorary Mention at Ars Electronica in the category of Hybrid Art in 2013 [2], among other awards [3]. Further scientific and artistic papers and presentations were derived from this project, such as research on atomic aesthetics [12].

In hindsight, the momentum created through the *dS* project – along with the cross-disciplinary knowledge exchange from which it arose [22] – established a trans-disciplinary legacy of ongoing research directions. Two specific aspects of *dS* in particular are worth highlighting in this context: (1) the algorithms created in order to represent the human body as an energy field and facilitate real-time interaction with atomic physics simulations; and (2) the aesthetic approach in which people see their reflection (and the reflections of others) not as a body would appear in a conventional mirror, but rather as a kind of luminous energetic form. In what follows, we discuss each of these in turn.

The *dS* interaction algorithms were described in detail by Glowacki et al. in 2014 [25], along with a proof-of-principle demonstration showing human users interacting with depth sensors to guide real-time GPU-accelerated molecular dynamics simulations. In 2018, this interaction strategy was adapted to VR environments, establishing a new paradigm for human interaction with real-time molecular physics simulations, which O'Connor et al [46] named "**i**nteractive **M**olecular **D**ynamics in **V**irtual **R**eality" (iMD-VR). Several subsequent studies have since illustrated the benefits of iMD-VR in different domains. For example, iMD-VR: (1) accelerates the visualization and manipulation of complex molecular topologies

Figure 1: Left: 360° dome installation of *danceroom Spectroscopy* during an education event in Bristol, UK (Photo by Paul Blakemore). Right: The project featured on the cover of *Leonardo* journal, 2016, Vol. 49, No. 2. [42]

in 3D [46]; (2) enhances the learning experience of undergraduate and masters students in chemical science [7]; (3) accelerates the process of curating data sets in the molecular sciences, which was demonstrated to increase machine learning rates by a factor of ~10; [6] and (4) supports research into the mechanisms by which drug molecules bind to proteins. [13, 14]. During the COVID pandemic, iMD-VR found use as a tool supporting researchers investigating drugs to target the Sars-CoV-2 virus. [9]

The rendering strategies used within dS to represent bodies were intentionally minimal. For example, Mitchell et al. commented on how this aesthetic encouraged people to reimagine themselves as forming a continuous energetic field with their environment. [42] Such a perspective stands in contrast to the ways we normally imagine our bodies – i.e., as solid, separate, localized, and bounded material objects. Glowacki has since defined this approach to bodily representation as a 'numadelic aesthetic'. [24] In the last few years, this numadelic aesthetic was adapted to VR. A series of neuroscientific studies have since shown that numadelic VR can elicit so-called 'self-transcendent experiences' (i.e., subjective experiences which diminish egoic identity and foster a sense of connection) which are comparable to those elicited by psychedelics. [26, 27] Moreover, Kettner et al. have shown that numadelic VR offers a potential new treatment option in helping to alleviate the fear and anxiety that often arises for those who are facing life-threatening illness [32]. The IRL is currently being funded to investigate the efficacy of a numadelic VR experience called 'Clear Light', which is being designed to help those who are facing life-threatening illness, including patients, their carers, and their friends and loved ones.

3 Original Technology of *danceroom Spectroscopy*

3.1 Custom Hardware

To get usable image data from people in the interaction zone without requiring constrained lighting conditions, *dS* used an array of depth cameras. The system can utilize up to 8 cameras in a custom mount for 360° environments [25], or an array of 2-3 sensors for a flat screen installation. At the time, the original 2010 Kinect for Xbox 360 was just introduced as an affordable and *hackable* device.

dS relies on a custom workstation with an Intel i7 3.2 GHz 16 core CPU and 2 graphic cards: an NVIDIA GTX Titan for physics computations, and an Asus HD 7970 DirectCU II for graphics output.

3.2 Software

The custom workstation runs a frozen-in-time version of Windows 7. The Visual Studio project is close to 50,000 lines of code written in C# using the .NET framework. The OpenNI library is used to acquire image data from depth sensors, and does image processing using OpenCV. Particle motion simulation is implemented with a custom GPU accelerated physics algorithm on OpenCL, and graphic rendering is carried out using SlimDX - a DirectX wrapper.

3.3 Sonification

Sound in *danceroom Spectroscopy* is played on a separate 2011 MacBook that receives the atomic analysis data through the OSC (Open Sound Control) protocol [21]. The data analysis comes from the physics simulation computations, and is produced by three types of process: particle collision detection; the conformation and movement of particle clusters; and vibrational analysis of the system's energy using Fast Fourier Transform (FFT) [21], [31]. The data is sent via OSC to an Ableton Live project using samples and Max/MSP patches which produce the sound.

Additional sound-related experiments were conducted using *dS* by Joseph Hyde in 2013 and 2014 [31], where the system's simulation parameters were live controlled by sound sources from professional music players via MIDI and OSC signals. He also experimented with an idea of a "feedback loop" in the project called *Cloud Chamber*, "where sound is controlling the simulation but is itself produced by the simulation" [30].

3.4 Hardware and Software Obsolescence

More than a decade after its creation, the *danceroom Spectroscopy* (*dS*) project faces critical obsolescence issues arising from a deep entanglement between its specific, aging hardware and complex, largely undocumented software. This situation presents significant challenges to its long-term survival and exhibition potential.

The installation depends on a unique combination of hardware components like the custom-built workstation, and the crucial Microsoft Kinect sensor, now discontinued (Kinect for Xbox was discontinued in 2017 [48], followed by its successor, Azure Kinect, which was discontinued in 2023 [50]). The current software is tailored to the specific hardware setup, and there is not sufficient documentation or institutional knowledge to make necessary changes in case of a necessary hardware update. This limits the exhibition potential to the specific location where the workstation is currently stored, and without available backups.

The lack of documentation and deep hardware dependency mean that even if identical hardware components could be found, confidence in successfully replicating the software environment to create a second functional installation is low. Even minor alterations, such as automated updates to drivers or the operating system, pose a significant risk of destabilizing the entire installation. As a necessary precaution, the workstation is kept permanently disconnected from the internet.

To ensure *dS* can survive, also to open it up to a wider artistic community who may be interested to support its development, the implementation of new preservation strategies addressing both hardware and software vulnerabilities are needed.

4 Preservation Through Interpretation

dS is an example of interactive digital art and it encapsulates the unique nature of this genre: it is not just an object, but a system that relies on the performative role of the spectator [53]. This aligns with the observation that, from a conservation perspective, electronic works often share more characteristics with performance art than with traditional physical artifacts [8]. Simply, it is much more about what an artwork does and what effects it produces, rather than what it is made out of.

However, hardware and software systems, that facilitate interaction and responsiveness in an interactive artwork, are subject to fast obsolescence, which can lead to an irreversible loss [17]. As Wendy Hui Kyong Chun describes, software operates through a powerful illusion: it presents itself as a stable, storable, and perfectly reproducible medium, yet it is fragile, dependent on ever-changing hardware and operating systems that eventually stop updating [10].

This paradox can be further deepened by considering interactive digital art as a *digital object*, as described by Yuk Hui. Here a digital object is not a static entity but is constituted by its internal and external relations to its own code, to its hardware environment, and to its users [29]. This inherent ephemerality, masked by an ideology of permanence [10], forces a reevaluation of traditional preservation methods.

4.1 Strategies of Digital Art Preservation

These are the main strategies that are currently implemented in terms of preserving digital artworks [15]:

- *Storage*: This is the default preservation strategy since the invention of the modern museum in the Western Enlightenment [39]. In case of digital art, it means saving physical media or the original hardware and necessary supplies in a storage space. These tactics work only in a short-term because of fast hardware obsolescence, leading to short production lifespans.
- *Emulation*: This strategy uses hardware and software emulation to avoid the need to physically maintain obsolete hardware, and does not require modifications to the artwork's source code, so it retains the original look and "feel". For example, this strategy is implemented by Rhizome for the net art projects [16].
- *Migration*: The migration of an artwork to a contemporary medium. Usually, this methodology includes transferring data from VHS, DVDs and CD-Roms to more accessible formats, or, in the case of a software-based art, adapting the code to run on modern computers.
- *Reinterpretation*: This is the most radical preservation strategy. It ensures that the artwork remains a living expression, rather then a relic, by rewriting the code to a completely different platform, as well as translation into a new, often contemporary context. This type of art preservation also enables artists and curators to explore new ways to present

an artwork. Crucially, choosing reinterpretation necessitates a shift in how authenticity is evaluated; rather than focusing solely on the integrity of the original digital object, authenticity is judged by the fidelity to the work's core concept or essential characteristics [51].

4.2 Choosing Appropriate Preservation Strategy For *dS*

Initially, *dS* relied on the storage strategy by default: the hardware was stored in the IRL space and was used for occasional demonstrations. However, the inherent limitations of this preservation approach soon became apparent. The main challenge arose from hardware obsolescence, specifically regarding the first generation Kinect depth sensors, no longer manufactured, but still the primary input mechanism for the installation. Furthermore, the installation's reliance on a custom processing tower, and a mandatory connection to a separate laptop running an Ableton Live project for sonification, significantly burdened the portability for exhibiting the work outside the IRL.

Alternative preservation strategies were evaluated. Emulation was considered unsuitable due to the computationally intensive nature of the scientific simulations that lie at heart of *dS*, which would put an excessive load on any emulated environment. Thus, migration and reinterpretation were left as most viable pathways.

The decision to choose reinterpretation over migration was driven by several factors: (1) it offered greater artistic freedom to adapt the work; (2) it provided an opportunity to implement performance optimizations and architectural improvements; and (3) crucially, it aligned with newly defined values for the new project.

These values emphasize keeping the artwork "alive" through open-source release [4] and enabling community remixing. They also aim to treat this project as an opportunity for collaboration and the creation of new projects—just as *dS* was in its time. To achieve this, software and hardware dependencies should be minimized, and the system's overall flexibility and modularity should be enhanced.

Furthermore, the choice of reinterpretation over migration was a conceptual decision rooted in the nature of interactive art. To treat *danceroom Spectroscopy* as a simple set of files to be migrated would would prioritize its status as recorded data, a static text, falling into the trap of confusing the source code with its live execution and the experience it produces [10]. In contrast, reinterpretation acknowledges that the artwork exists as a set of experiential and aesthetic relations between entities that must be re-established [29].

Significant transformations resulting from this reinterpretation process ultimately led to the adoption of a new name to reflect its evolved state - *esencia.*

4.3 Examples of Reinterpretation as Preservation Strategy

Several projects and artworks serve as compelling examples of reinterpretation as a viable preservation strategy for interactive digital art.

Centro di Sonologia Computazionale (CSC) in University of Padova adopted a reinterpretation approach to preserve an interactive musical installation in 2022 [18]. The work *Il caos delle sfere* by Carlo De Pirro, a composer who passed away in 2008, was first shown in 1999 and has been installed several times until 2004. In this installation, the Yamaha Disklavier, a self-playing acoustic piano, was combined with a pinball machine, aiming to bring contemporary music to a wider audience through interactive engagement.

The process of preservation of this artwork involved migrating the original computer system to a modern Arduino board and rewriting the source code, while preserving the original pinball machine and Disklavier. The primary focus remained on preserving the artwork's core identity, the interactive experience, and the intended function, rather than solely focusing on maintaining its original material composition.

Marc Lee's net-art project *TV Bot* represents how artists can take an active role in preservation of digital art through reinterpretation [28]. The *TV Bot* software indexes, analyzes and verifies information on the Web. The version 1.0 was created in 2004 using RealPlayer. By 2010 it became outdated due to adoption of Adobe Flash Player. Lee himself upgraded the artwork to a new standard, renaming it to TV Bot 2.0. This was not just a technical update, but a response to a changed way of information consumption: the updated version incorporated Twitter feeds. By 2016, TV Bot 2.0 again faced obsolescence as Adobe Flash Player was no longer supported, and the web standard shifted to HTML5. By this time, Lee had already released a new iteration, TV Bot 3.0. The work was reinterpreted again in 2020 as a response to the SARS-CoV-2 pandemic, renamed again to Corona TV Bot [34]. The artist's willingness to adapt the work to new platforms and integrate new functionalities highlights a dynamic approach to preservation that differs from traditional institutional methods focused on maintaining a static original.

Both these examples illustrate the efficacy and versatility of reinterpretation as a preservation strategy for interactive digital art. They demonstrate that focusing on the core experience and performativity of an artwork, rather than adhering to its original technical form, allows it to remain relevant and accessible across changing technological and cultural landscape.

5 *esencia:* reinterpretating *dS*

For this reinterpretation, our reference resources consist of: physical access to the only remaining hardware and software environment where *dS* still runs, which contains a version of the source in the original development environment (Visual Studio); access to one-on-one conversations with one of the original collaborators, and the published papers, images and videos regarding this artwork [23].

It is also worth mentioning that *dS* source code became extremely complicated and bloated owing to various ad-hoc modifications designed to test various ideas and to accommodate the range of installation and performance contexts. Although *dS* is still in operational state, the development environment is fragile. One of the first in-depth technical interventions we had to do, was fixing the development environment, so we could use the debugger to identify relevant portions of code responsible for specific behaviors.

5.1 Architecture and new dependencies

The software framework used in *esencia* is openFrameworks [37] (oF) version 0.12.0, an open source C++ toolkit designed for creative coding. It was chosen for its great performance, extensibility, and

Figure 2: Comparison of two systems. Top: Screenshot of performing *esencia*; Bottom: Screenshot of performing *dS*

track record longevity. oF was first released in 2005 and still widely used and maintained by the community to this day. It has been used to produce multiple digital art projects [36, 38, 41] supporting custom integrations across graphics, audio, networking, and hardware I/O, and has consistently proven to be a reliable and robust framework for interactive installations.

We structured the software in four major modules (figure 4): (1) video processing to handle video sources and image processing; (2) simulation engine to compute particles movements and energy fields; (3) renderer to compose the simulation data and video layers with the required visual effects; (4) user interface to expose all relevant parameters for the different systems. Modules are interconnected by groups of shared data parameters (using the standard oF's *ofParameter*), to achieve as much independence as possible. There are two main applications. The main app contains the core modules: video processing and simulation engine, plus the GUI. The independent render app runs as a client to draw and compose particles with video feed and apply visual effects.

This configuration follows the modularity principle that allows us to 1) manipulate the render app window independently (i.e., setting full-screen window mode on a specific monitor or projector), and 2) facilitate us and others to make changes or even replace parts of the system.

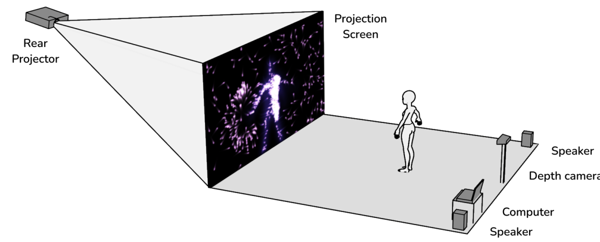

Figure 3: Setup for *esencia*

While *esencia* is still in development, the core features are already implemented. The project is currently around 2,500 lines of C++ and GLSL, around 5% of the ~50,000 lines constituting *dS*. However, *dS* included significant portions of code now considered part of the oF framework and used addons, like OpenCV or OpenNI. This can be understood as a sign of the evolution of digital tools towards higher abstraction, allowing artists and developers to focus on creative expression rather in low-level implementation; as well as emphasis on modularity, specialization, and open source ecosystems. *esencia* benefits from this, a smaller codebase is easier to document and maintain.

Figure 3 shows a typical setup for *esencia*, where a rear projector is used, and the depth camera is behind the interaction zone. The rest of the items, stereo speakers and computer, can be distributed around the available space.

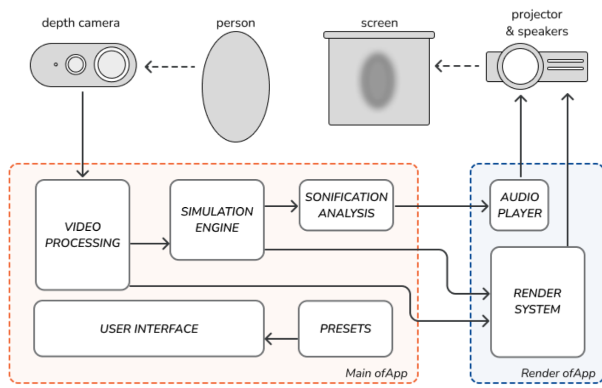

Figure 4: Architecture of the *esencia* project

One important feature of the oF framework is the *addons* system, to extend abilities through external code and libraries shared by the community. *esencia* uses the following: *ofxOrbbec* [52], a wrapper for the Orbbec depth camera API; *ofxGuiExtended* [49], a GUI library with customization features; and *ofxPresets* [5], a preset interpolation and sequencer.

5.2 Image processing

As stated before, Microsoft discontinued the production of Kinect devices in 2017 and Azure Kinect in 2023. However, they licensed their latest technology to a couple of manufacturers [48], mostly for robotics and manufacture facilities.

During the pre-production phase, we searched for a replacement for the Kinect cameras. Our evaluation considered: depth sensing technology, FOV, operational distance range, development support (API), and price. Despite newer depth sensing technologies have been developed, like the Stereolab's RGB binocular vision (Neural Stereo Depth Sensing), we preferred a similar IR dot projector technology like in the Kinects. IR projection performs better in most lighting conditions, including low light environments, as it has been in *dS*'s exhibitions. The Intel RealSense product line has been a reliable Kinect replacement for art projects, but we discarded it because their latest oF addon was built for oF version 0.10.1 (released in 2018) and we aim to use the latest oF version 0.12.0. Finally, we selected *Orbbec Femto Bolt* depth camera [1]. Compared to the first generation Kinect, this camera offers larger FOV (120° x 120° vs 45° x 65°), better depth resolution, and reduced point cloud noise. This allows the use of only a single camera for flat-screen installations, whereas *dS* requires an array of 2 or 3 devices. The availability of the *ofxOrbbec* [52] oF addon for oF 0.12.0 was also crucial, so we could focus on the artwork reinterpretation instead of writing and maintaining libraries for the camera. So we greatly benefit from the generous contributions of the oF community.

Following the value of modularity, we treat the depth camera data as a video feed to create "energy landscapes", so it would be easy to replace this camera with a different model or brand in the future if needed. The depth video image processing, as shown in figure 5, performs silhouette extraction from the defined interaction zone, using a single background reference frame. For each video frame, it does the following:

(1) Applies a high and low-value filters on the background reference and the live frame. Since the depth data encodes distances, this filter removes most of the unwanted background environment outside the interaction zone.
(2) Subtracts the filtered background reference from the filtered frame, using a regular OpenCV *absDiff* function.
(3) Threshold the subtracted frame as a pure black and white image to obtain a mask covering the relevant regions in the image.
(4) Uses the mask over the original video frame to extract the segmented image. This is the key step in our extraction method.
(5) Applies Gaussian blur over the segmented image to smooth the edges. This attenuation helps the particles to interact with the energy fields smoothly.
(6) Prepares the image for blending into the composed projection. While other methods can be used, we are currently generating a transparent-shaded image from the grey-scale segment.

For the majority of the process we use standard OpenCV functions already provided by oF. The later Gaussian blur was implemented on GPU using fragment shaders, as it is a computationally intensive process, that is more effective when computed in parallel [44]. This smoothing step in *dS* was implemented using so-called Gaussian-Hermite quadrature iteratively on each particle [25]. Now we simply apply Gaussian blur over the entire image, achieving a similar "feel" as the original approach.

Figure 5: Screenshot of a prototype app used to test the image processing workflow over a single frame

It is worth saying that the background processing in *dS* was much more complex due to the lower signal/noise ratio, and the lower sensing resolution on the Microsoft Kinect camera, compared to the Orbbec Femto Bolt, requiring to sample hundreds of frames to create a reliable filter reference. Using newer depth cameras allows us to work with a single reference frame to perform the background subtraction.

5.3 Physics simulation

The interactive nature of the artwork is driven by a custom simulation engine. This engine: 1) calculates the motion and interaction of thousands of individual particles, 2) enables a thermostat control system for maintaining thermal equilibrium, and 3) integrates a force field derived from a preprocessed depth image. *esencia* uses the same simulation principles as *dS* (interparticle interactions and energy landscapes), that are described fully in Glowacki et al. [25]. However, the implementation is different: while *dS* simulation engine is built using Cloo OpenCL wrapper for .Net, *esencia* relies on OpenGL compute shaders for parallel computations.

Compute shaders are a distinct programmable stage within the OpenGL graphics API, specifically designed for general-purpose computational tasks on the GPU [11]. Unlike traditional graphics shaders (vertex and fragment) that are tied to the rendering pipeline, compute shaders can operate more freely on arbitrary data buffers. However, both compute and graphics shaders use the same programming language: GLSL, or OpenGL Shading Language.

This makes compute shaders an optimal choice for graphics applications with parallel computation: they provide a high degree of control over the GPU's computational capabilities with a language that is already used by media artists and creative developers.

Despite the fact that OpenCL and OpenGL are both GPU parallelization technologies, we used OpenGL for the following reasons: the simplicity of the API and oF integration, the convenience of using a more familiar language (GLSL), and better performance results in our preliminary tests.

For our simulation system, all particle data (position, velocity, radius, mass) is stored in a dedicated GPU memory location, accessible to the compute shader. The GPU executes shader code using many threads simultaneously, organized into workgroups. Each thread has a unique identifier, allowing to update the state of one specific particle. Thus, the simulation step for the entire particle set can be performed in parallel.

The interaction between particles is computed using the Lennard-Jones potential. This is a model that is commonly used in physics and chemistry to approximate the interaction between pairs of atoms. It simulates two fundamental forces: strong repulsion at a short range, and attraction at a moderate distance [35]. Our implementation calculates this interaction force for each pair of particles.

Besides interparticle interactions, the simulation incorporates real-time input from a preprocessed depth image. This allows the audience to directly influence the particle system by dynamically shaping an "energy landscape" - a topological map of forces that an atom "feels".

Captured depth data is preprocessed and provided to the compute shader as a 2D texture. Each particle's current position is mapped to the corresponding coordinate within this depth texture. The system then calculates the local gradient of a depth field at the location of a particle. This is done by sampling the depth values of adjacent locations horizontally and vertically to compute finite differences, determining the direction and steepness of the slope in the depth landscape at the current point.

The gradient vector is then scaled by a parameter that determines the nature of the interaction: a positive scaling factor causes particles to flow away from user's energy landscape; or a negative scaling factor creates an attractive effect, drawing particles towards the audience's silhouette. The magnitude of the scaling parameter controls the strength of this interaction. The resulting force is added to the particle's total force, allowing the energy landscape to guide the movement of particles alongside internal forces.

To maintain a desired speed of particles or "temperature" within the simulation, an optional thermostat mechanism can be enabled. It calculates the kinetic energy of a particle and compares its implied temperature to a target temperature value. Then, it calculates a scaling factor to adjust the particle's velocity, changing its kinetic energy towards the target level. This helps to control the simulation dynamics, preventing either stagnant or overly chaotic behavior.

The new system was tested on gaming laptops with an NVIDIA GeForce RTX 4070 GPU. Because the frame rate on *dS* is locked to 60 FPS, we compared it with the same setting on *esencia*. The figure 6 shows that our system outperforms *dS* without requiring the use of two graphic cards for separated simulation and rendering processing. We also included unlocked FPS values to demonstrate good performance of *esencia* even with high number of particles.

This performance improvement reveals an additional opportunity from the reinterpretation strategy: better results can be achieved using modern, standard hardware and up-to-date software tools; often outperforming what was previously only possible with high-end, top-tier hardware of earlier generations. However, we currently treat this improvement as a benchmark. For the flat-screen installation we do not enable more than 5000 particles to avoid distorting the original artwork look and feel. Higher particle count can be used on future wide- or multi-screen installations.

5.4 User interface

The user interface in *dS* provides real-time access to modification of a significant number of parameters. They were grouped into seven contextual tabs: cameras, image composition, sonification analysis, OSC and MIDI communication, physics dynamics along with their visual properties, and particle grouping variances. The combination of parameter values result in "an enormous number of distinctly

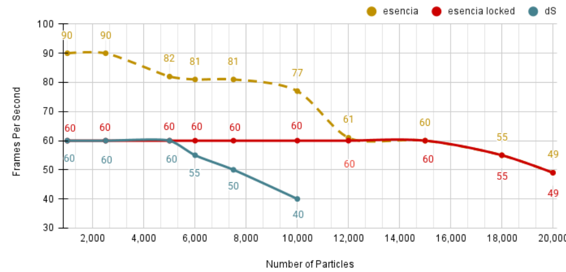

Figure 6: Performance comparison. Frames per second by Number of particles. Legend description: *esencia* - unlocked framerate, *esencia locked* - framerate locked to 60 fps, *ds* - default configuration

different states" [21]. Those combinations can be saved as preset scenes and applied with smooth interpolations across each preset.

It is in control panels where software self-represents itself and where the regulation of user and machine expectations occurs [47]. Aiming to escape *screen essentialism* [33] (by focusing solely on the onscreen appearance, oversimplifying its materiality) the design process for the esencia (operator's) user interface focused on two principles: expose the internal components of the system and encourage exploration.

esencia's user interface (figure 7) is the most significantly dissimilar element in the reinterpretation of *dS*. While the original *dS* displays standard flat custom-made UI elements grouped in tabs, *esencia* uses a flowchart metaphor similar to visual or node-based programming, where conceptual nodes and their links visually represent the internal relationships and flow of data through the system.

The use of metaphors in user interface design allows closing gaps between the user's mental model and the system's functionality, by using a familiar language, symbols, and references [43]. In *esencia*, the metaphor of flowchart serves the purpose of describing the abstract dependencies between processing nodes (i.e., "video sources node" connects to "video processing node"), helping to communicate the internal complexity of the system on an abstract level. The use of a node-based visual programming aesthetic, appeals to some sectors of the creative software community, as it is a popular programming paradigm to simplify the user's technical attention, allowing them to focus on modeling the system through individual processes. In *esencia*, the "nodes" are already interconnected, but the links are fixed, situating the node-based visual style as a fictional user interface [19], this creates a non-functional stimulus reinforcing user exploration-learning dynamics [43].

Lastly, as in *dS*, *esencia* includes preset management for saving and loading combinations of parameter values. An important feature for a smoother experience is the interpolation of parameter values while changing presets. For *esencia* the preset system also includes a preset sequencer to facilitate designing specific sets of experiences. The preset management, parameter interpolation, and sequencer functionality developed for *esencia* resulted in an oF addon named *ofxPresets* [5], also released open source.

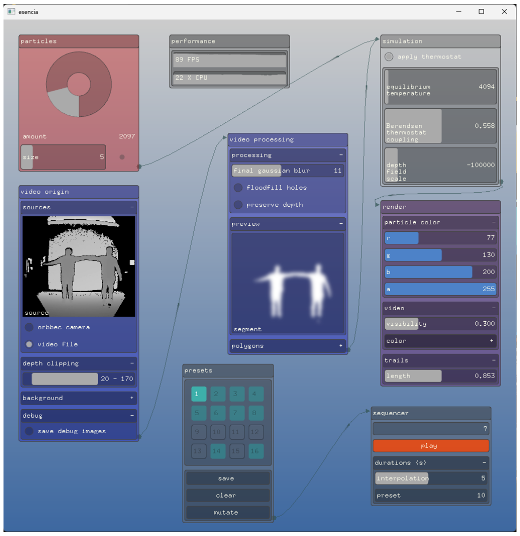

Figure 7: *esencia* user interface uses a node-based fictional user interface metaphor

5.5 Render system

As already stated, the render system is only a client to compose and paint all the processed elements on the projection screen. The current implementation draws over *frame buffers* using regular oF drawing routines, applies visual effects and composes the final scene. Currently, the processing pipeline is the following: 1) Saves a copy of the last frame; 2) Clears the screen with a transparent color according to the general *VFX trail factor*; 3) Draws the post processed extracted frame from the video feed, corresponding to the force field, modified by a *visibility factor*; 4) Draws every active particle from the simulation as ellipses; Adds an additional VFX to the final blend, currently a two pass blur filter.

6 Discussions

The decision to frame this project as an act of preservation through reinterpretation, rather than simply as a technical remake, is a deliberate one that engages with a challenge in digital art conservation. While *esenica* can be considered a remake form a technical point of view, which implies the recreating an original with updated visuals and technology, its foundation aligns with a radical, but necessary preservation methodology.

This approach was defined in "Permanence Through Change: The Variable Media Approach", which recognizes reinterpretation as a necessary strategy for artworks whose identity is tied to their behavior rather than their specific physical medium [15]. It was further developed by LIMA, Platform for Media Art in Amsterdam [53]. This strategy also shares principles with an established reenactment approach in performance art, where the artwork's existence is renewed through new instantiations [20]. Our choice was necessitated by the failure of the default storage strategy, as detailed in section 4.2, which risked the permanent loss of the artwork.

Thus, the distinction between a remake and a preservation through reinterpretation lies in the foundational intent of the described project: a commitment to carrying forward a key feature of the original artwork in a changing context: the creation of an environment that fosters co-participation and gives rise to derivative projects.

The adoption of a new name is not a suggestion that this is a separate, "inspired" work, but rather an act of curatorial transparency. This decision was made in conversation with one of *dS*'s original creators, acknowledging that while the core experience is preserved, the technology and context has evolved. It respects the historical specificity of the original artifact while clearly designating *esencia* as its living interpretation. We deliberately explore this risky but promising strategy, presenting a concrete case study to contribute to the important debate about how to keep born-digital works alive.

7 Conclusions

While there are still features to implement (i.e., sonification analysis, additional VFX, projection settings, and possibly external communication), the current status of *esencia* as a *dS* reinterpretation is at a stage which is sufficient to showcase it at the *Intangible Realities Laboratory* , resulting in similar reported experiences from old and new participants according to the original reports [42]. Additionally, *esencia* has also been useful to communicate the scientific principles behind its functionality, and how that led to further molecular dynamics development. Furthermore, the reinterpretation approach has been well received by people who have also experienced *dS* in the past, and promoted discussion around preservation of digital artworks.

We selected newer and stable software frameworks and updated hardware; however, we are aware that they may and will become obsolete or discontinued at any moment. So, the modularity approach allows outdated elements to be replaced easily. The reinterpretation approach enables us to implement new methods and improve functions that existed in *dS* in different ways, thanks to improvements in the quality of the data (like the simpler background subtraction process), and modern framework features (like the APIs that simplify running our physics compute shader pipeline). Without major feature sacrifices, we achieved a better system performance compared to the original artwork, enabling us to simulate a system with higher particle count, without dropping the 60 FPS target.

Finally, we would like to highlight this paper as an important part of the preservation process, serving as an extended project documentation.

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