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VR Kino+Theater:
a platform for the future digital media

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Fig. 1. Platform Logo.

VR Kino+Theatre is a media platform that combines theatrical performance with live cinema using virtual reality technology.

CCS Concepts: • **Computing methodologies** → *Graphics systems and interfaces*; • **Applied computing** → *Media arts*;

Additional Key Words and Phrases: virtual reality, real-time cinema, immersive theatre, storytelling

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1 INTRODUCTION

Currently technological developments are influencing new trends that begin to forge emerging tools and language forms and will shape the future of media.

1.1 Technology

In the past recent years, technology advances in Computer Graphics approached a rupture point that announces significant changes in the field as a whole. In particular, Modeling, Animation and Rendering are reaching new levels.

Image-based methods, such as Photogrammetry and HDR Light Capture, make possible to model both geometry and appearance from real-world data. Motion Sensing techniques allow to fully tracking the dynamics of humans, including body, facial expressions and eye movements. Real-time Global Illumination and Physical Simulation algorithms incorporated into GPU accelerated game engines, such as Unity and Unreal, provide an unprecedent degree of realism and interactivity.

Furthermore, VR / AR and plenoptic display hardware are liberating the viewer from the limitations of a rectangular 2D screen.

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1.2 Trends

As a consequence, these changes open up a wide range os possibilities that are being incorporated into many new media modalities. Some examples are: 360 degree videos, Live Cinema, Immersive Location Experiences and VR Theater.

1.3 New Languages and Tools

The main challenge to shape the emerging medium is the development of a new language, supported by suitable creative tools, making possible content production. In that respect, initiatives from organizations like the Oculus Story Studio [17], Google Spotlight Stories [2] and the ILMxLab [12], are already exploring this unchartered terrain.

1.4 Into the Future

On the other hand, a few concrete products recently released give us a glimpse into the future. Some notable examples are: the SIGGRAPH Real-Time Live and VR Theater programs, the Adam series by Unity / Oats Studio [20], the Hyper-Reality Experiences from VOID [22] and the Holojam creations from the NYU Future Reality Lab [14], *Holojam in Wonderland* [3] and *To be with Hamlet* [15].

Nonetheless, the quest for the next form of audio-visual communication and entertainment is still in the very begining — no definitive answer is in sight yet. The problem is complicated by the fact that a solution needs to balance financial, cultural and other aspects in order to be viable for the industry. A strong testimony of this dilema is the MIT Technology Review article, by Ty Burr, entitled "Hollywood Has No Idea What to Do with VR" [1].

2 THE VR KINO+THEATER PLATFORM

VR Kino+Theater [11] is our contribution to a long term solution for the above mentioned problem. The platform integrates traditional forms of entertainment (theater and cinema), with advanced interactive media, (virtual reality and gaming). In this way, it solves at the same time scalability of audience and presentation familiarity, while providing greater flexibility for innovative alternative formats. Think, for example, the possibilities for a Broadway show.

2.1 The Pillars

The foundations of our proposed solution lies onto three pillars related to technological, production, and delivery aspects which, we believe are the directions for the future.

On the technology front:

i) Exclusively 3D content captured from real data with the help of advanced sensors and machine learning;
ii) Procedural and real-time physical simulations powered by high-end graphics hardware;
iii) Distributed systems interconnected by low-latency wireless networks.

On the production side:

i) Completely unified process, in terms of both ubiquitous data access and augmented content generation;
ii) Collaborative real-time integrated authoring shared by all members of creative teams.

On the delivery scenarium:

i) Completely diversified media and application options;
ii) Multiplicity of presentation formats;
iii) Stratified and complementary fruition allowing to fully explore the content in many forms.

2.2 People's Roles

The operation of an ecosystem based on these principles entails new roles for producers, performers and participants.

The content producers: director, art designers, cinematographer, composer and other technical people benefit from a powerful creative environment.

The performers: actors, musicians, director expand their expression capabilities with VR interactive tools.

The participants: general public and aficionados have a wide range of possiblities to experience content at various levels and in different modalities, from passive to immersive and interactive.

One important aspect of the platform that has a significant impact on the people's roles is communication. Since ubiquitous networking is part of its technology pillar, all players in the VR Kino+Theater ecosystem can fully interact in a transparent and effortlessly way.

Furthermore, this interaction is mediated by the system, which means that all exchanges can be incorporated into project's knowledge automatically.

3 SYSTEM ARCHITECTURE

The architecture of VR Kino+Theater is designed to be compliant with requirements described in the previous section.

3.1 Logical Components

The logical components of the system are: the *Kino+Theatre Engine*; the *Action Manager*; and the *Sound Manager* .

The Kino+Theater Engine is embedded in all programs of the platform to support interoperability.

It is composed of (See Fig. 2):

- *KT Communication Layer* – responsible for connection with the Action / Sound Managers;
- *KT Core* – that implements content-related functionality,

In our current implementation, the Kino+Theater Engine is based on Unity[19].

Unity is a cross-platform engine, originally develeped for the game market, but evolved into a complete development system for 2D and 3D graphics, simulations and multi-user networked interactive applications. It supports more than 27 different platforms including practically all Virtual and Augmented Reality systems.

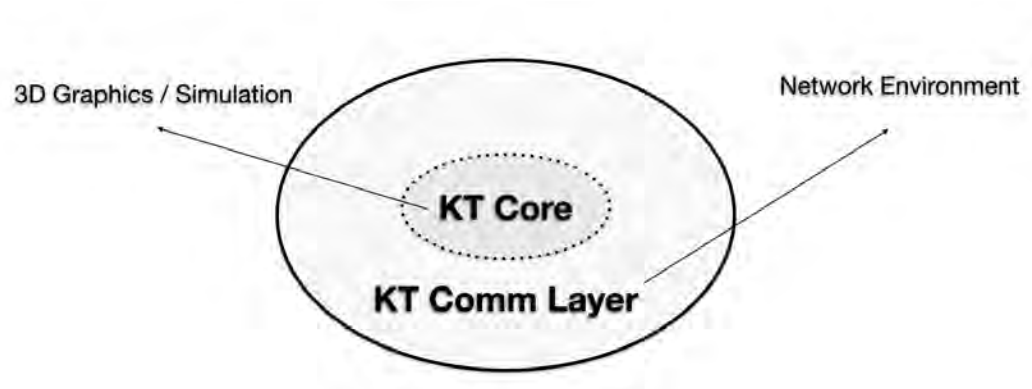


Fig. 2. VR Kino+Theater Engine.

The Action Manager deals with the seamless global distribution of motion and events within the network environment. See Fig. 3.

In our current implementation, the Action Manager employs the Holojam SDK.

Holojam is a server-client environment built for wireless shared-space virtual reality by the Future Research Lab of NYU [16]. It is integrated into Unity and enables the development of networked multiplayer VR experiences.

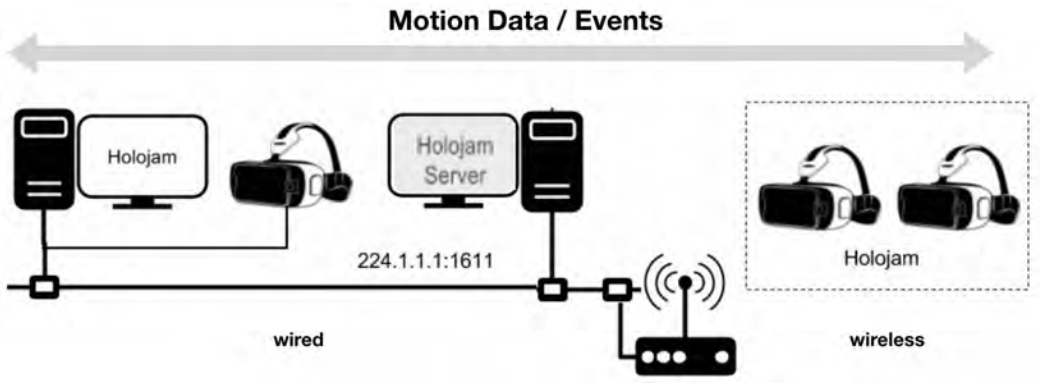


Fig. 3. Action Manager.

The Sound Manager controls the low-latency audio capture / transmission. See Fig. 4.

In our current implementation, the Sound Manager relies on Mumble.

Mumble is a voice over IP (VoIP) application, primarily designed for games. It uses a client-server architecture which allows users to talk to each other via the same server. Among its distinguishing features, are worth mentioning a very simple administrative interface, high sound quality and low latency [13].

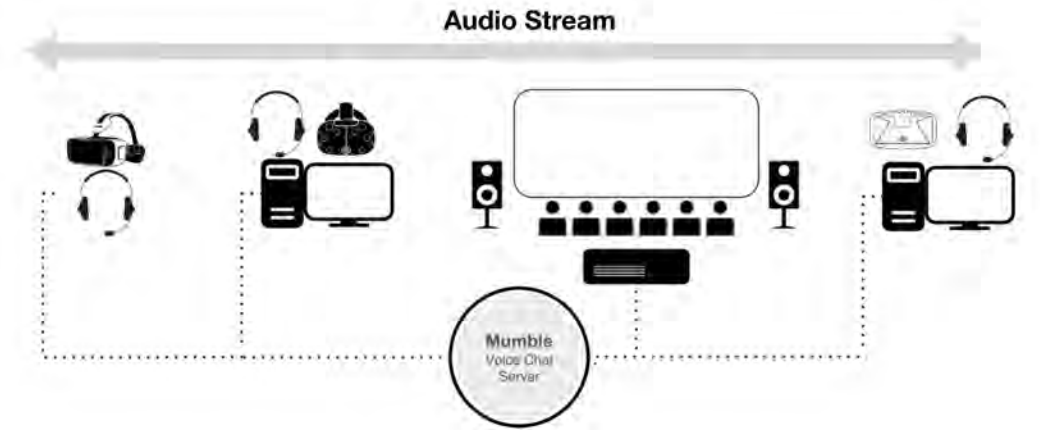


Fig. 4. Audio Manager.

3.2 Physical Environment

The physical environment of the system can be divided in two components: Network and AV (Audio-Visual) hardware/software. See Fig. 5.

The Network environment supports real-time data streaming and interconnectivity within a server-client structure. The hardware setup includes both wireless and wired high speed network infrastructure, as well as, backend servers, production workstations and related equipment. The software layer includes all the servers and communication management programs.

The AV environment delivers content presentation and interactivity – it includes VR Stages and other spaces with associated equipment. The hardware setup consists of the audio-visual equipment, such as sound systems, projectors, cameras, etc, and also the equipment for VR, graphics and interaction, such as Headsets and portable computers. In addition, the stages are equipped with various sensing systems for different purposes, for example Motion Capture.

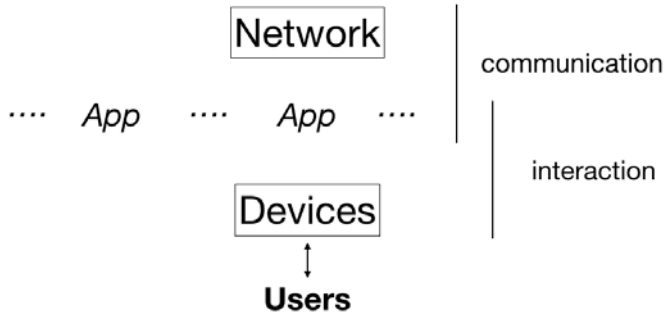


Fig. 5. VR Kino Theater Environment.

3.3 Data

The content used in the system is composed of dynamic and static data.

Dynamic data includes:

- *Motion*, from actors and objects;
- *Audio*, from actors and musicians;
- *Events*, triggers of cameras / effects.

Motion data, constitutes essentially of 6 DOF position/rotation tracking data of rigid bodies (i.e., a 3D vector and a quaternion). This is sampled and time-stamped. Audio data consists of streams of digital sound. Events are control signals that occur at discrete times.

Static data includes:

- *3D Models*, i.e., sets and props;
- *Avatars*, characters;
- *Virtual Cameras / Lights*;
- *Effects / Animation Procedures*.

The static content includes all data necessary to generate the 3D scenes for the experience, such as geometric models of the objects, textures, illumination maps, etc. It also includes structural and procedural data, such as scene hierarchies, skeletons of the avatars and programs for generation and control of models, effects and behavior.

3.4 Timeline

The system operates in real-time and, as a consequence, it is time-dependent. In that respect, the concept of a *Timeline* is essential.

A VR Kino+Theater experience, in general, has a script and a narrative that are associated with a timeline.

The experience is constructed, rehearsed, and presented. During these phases, the dynamic data of a session can be recorded to be edited and played – in a *kino+theater session* (.ks) file.

The session data structure has a timeline that includes the following elements: *Motion / Events Stream* ; *Audio Stream*; *3D Graphics Simulation Processes*.

Besides these data elements, the structure also contains *Metadata*, such as Tags and Markers.

Additionally, it may be stractified into *Layers*. This is useful to separate motion and audio from individual characters, for example.

4 PROCESS AND EXPERIENCE IN VR

The main goal of the VR Kino+Theater platform is the creation of narrative-based participatory audio/visual experiences. For this purpose, it leverages the methodology of consolidated traditional media formats, such as cinema and theater. However, at the same time, it expands their creative possibilities with advanced Interactive Graphics technology, in particular Games and Virtual Reality.

In the context above, the basis of the production process follows essentially the established patterns. On the other hand, the way that most procedures are executed are radically changed, under the influence of powerful new tools.

4.1 Process

The lifecycle of an experience involves three phases: *production*, *presentation*, and *memory*.

In the production phase, the content is created and is at this stage that most of the creative process occurs.

In the presentation phase, the experience actually takes place and is delivered to the public.

In the memory phase, the result of the experience is archived.

4.2 Functional Areas

An experience requires three types of areas:

1. VR Stages - for performance and interaction.
   It is used by the actors and active experience participants.
2. Control Areas - for operation of elements and parameters.
   It is used by the director to switch the cameras and staff members for general functions, such as sound / light changes.
3. Presentation Spaces - for content delivery. It consists of the movie theater and other viewing spaces for the audience.

4.3 Situated Participatory VR

Regarding the VR technology, the VR Kino+Theater platform features a modality that we call “Situated Participatory Virtual Reality” which combines full body tracking in tangible spaces with real / virtual objects [21].

The actors, beside the VR Headsets, use markers at various body locations (i.e., hands, feet, torso and head) for motion capture. This tracked data enables their avatar to be animated with inverse kinematics. Objects are also tracked to capture their rigid body motion.

This scheme makes possible to create shared virtual environments that can be either co-located (where users are in the same physical space) or remote (where users are in separate spaces).

Figure 6 shows two actors in a VR stage interacting with a cube.

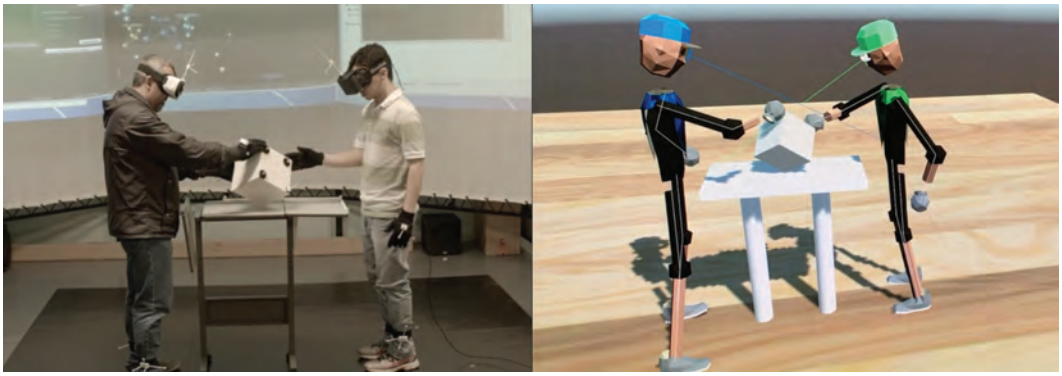


Fig. 6. Situated Participatory VR.

Although the platform makes use of VR, it also employs for presentation, regular 2D / 3D screen projections, each in its own appropriate space. In that way, participants could engage in an experience through different modalities, from fully immersive VR to a traditional Cinema screening.

4.4 Dimensions of Shared VR

In order to better understand the creative configuration spaces of multiplayer VR it is important to analyse the possible variations for the implementation of an experience.

Ken Perlin proposed a conceptual way to formalize this problem based on what he called "the Dimensions of Shared VR" [18]. He identified three distinct dimensions for characterizing the experience. They are: *co-locality*; *agency* and *liveness*.

In the context of a VR Kino+Theater experience, we find useful to include a fourth dimension: *immersion*.

Co-locality is the property of participants being physically present in the same place or being at separate locations but sharing the same virtual space.

Agency is the property by which participants are able or not to modify the outcome of the experience.

Liveness is the property of engagement by a participant in an experience while it is performed or only reviewing the result of an experience that has already happened and recorded. Note that is possible a scenario that part of the experience is live and part is not.

Note that interactivity requires both agency an liveness.

Immersion is the property of a participant being in a virtual reality scene using a VR equipment or not for engaging in the experience.

The VR Kino+Theater plataform allows a full exploration of this 4D configuration space with different variations in all the four dimensions described above. Furthermore, the platform also permits to create an experience that contemplates different configurations for specific groups of participants simultaneously.

5 SPACES

The VR Kino+Theater platform is all-encompassing in the sense that it allows a multiplicity of complementary presentation formats. As such, experiences can be delivered in various configurations of multiple spaces.

For example, the actors perform on a VR stage, while the director selects in real-time the views that are shown on the live movie projection screen.

5.1 Presentation Spaces

Presentation spaces can be classified into two basic categories depending on their relation with VR technology. They are: *Main Theater*; and *Experience Areas*. We can also consider a remote *Mobile Participation*.

Main Theatre

The Main Theater is the area for traditional non-immersive A/V presentation. It consists of the *seat section* for the audience, the *movie screen* for projection and speakers.

This area can also be complemented by a *backstage* , such as in many theater houses. In that configuration, the backstage can accomodate a *VR area* for the actors, as well as, a *Control Area* for the director.

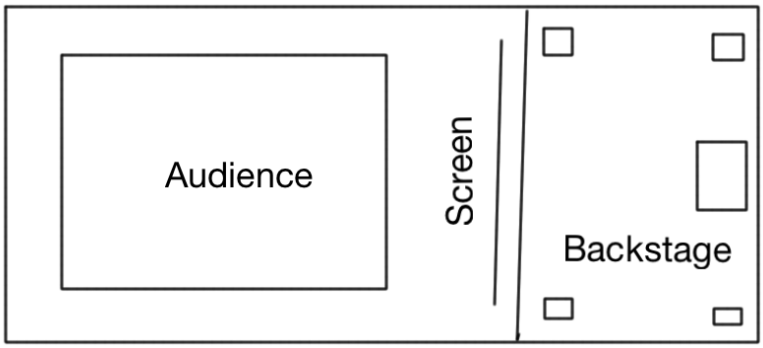


Fig. 7. Main Theater.

Such setup is sufficient for a minimal self-contained VR Kino+Theater presentation. See Fig. 7 and Fig. 8.

Fig. 8. One possible configuration of main theater space for VR Kino+Theater.

Experience Areas

The Experience Areas allow participants to enjoy new modalities of presentation using VR technology.

In this respect, an experience area can be configured in many ways depending on the kind of VR equipment and sensors incorporated into the stage.

The elements for stage configuration of an experience area include both the type of hardware and the required personnel to operate the stage with participants.

There are roughly three levels of configuration, as dicussed below and illustrated in Fig. 9:

Level 1. - This is the simplest configuration. The audience watch the presentation using a basic VR headset, such as the Google Cardboard. Participants view the scene from a fixed point with 360 degrees gaze rotation. The seats are allowed to rotate.

Level 2. - This is an intermediate configuration. The stage features special purpose seats with motor control. The VR headsets include rotation and restricted positional tracking. An example of this kind of device is the Oculus Rift. The VR equipment can include controllers for user interaction. Stages of this type need staff personel.

Level 3. - This is the most complete and sophisticated configuration. The participants use state-of-the-art equipement, such as the HTC Vive, that has unrestricted position an rotation tracking. The gear is untethered and complemented by sensors for body tracking. This type of stage allows a fully immersive and interactive experience. Because its characteristics it requires besides the techincal staff, a team of supervisors to coordinate the participants.

Fig. 9. VR Experience Areas.

It is worth noticing that the number of participants in each level of configuration is inversely proportional to the technological features included in the stage. This is a consequence of the way the experience is performed, as well as, the costs of the setup.

5.2 Engagement and Participation

The presentation spaces described above imply in an specific kind of participation by the public. While the main theater is designed for passive viewing, the experience areas support immersive interactivity.

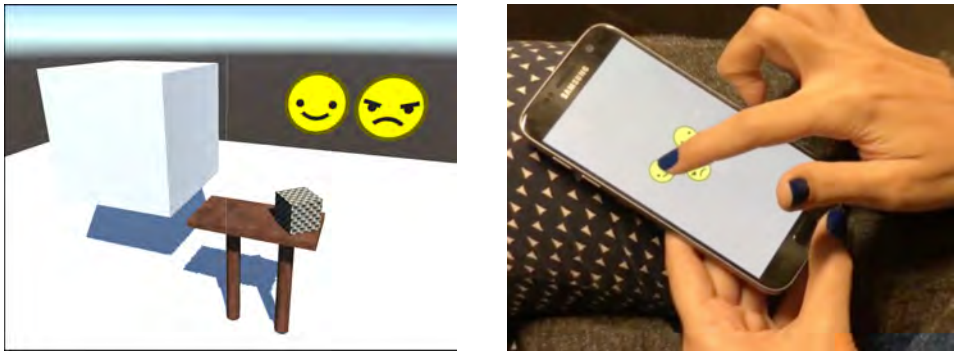
Another important aspect is the *participant engagement* in the experience. More immersion and interactivity demands a degree of involvement and previous knowledge from the users.

Mobile Participation

As mentioned above, the public may also employ a mobile device, such as an smartphone or a tablet, in order to participate in an experience.

In that respect, the mobile device can be used “in-site”, as complementary device during a live experience, or remotely – in that case, it may be while the experience is taking place of afterwards in a follow-up interaction (for instance, on social media platforms).

Figure 10 shows an example of user interaction through a mobile App. The participant controls an element of the scene in real-time.



Live Scene Interaction

Fig. 10. Mobile App.

6 SOFTWARE

The functionality of VR Kino+Theater is implemented as a suite of programs that contemplate the various aspects of the system operation. Below we list the categories of software and describe the main programs in each category.

6.1 Servers

Servers are programs that manage data within the network.

Holojam, for motion streaming;

Mumble, for audio streaming. See Fig. 11.

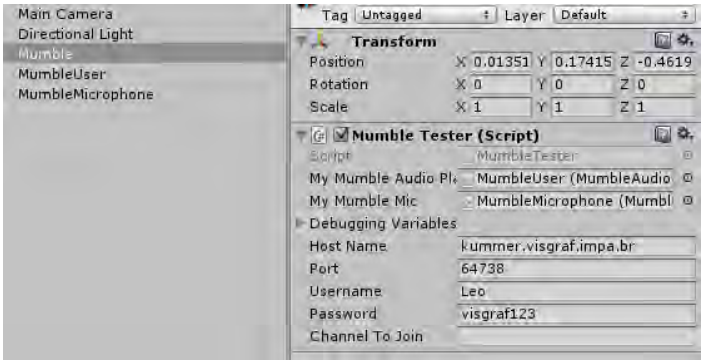


Fig. 11. Mumble.

6.2 Sensing

In the Sensing category there are programs that acquire data.

Optitrack Motive, for Motion Capture. See Fig. 12.

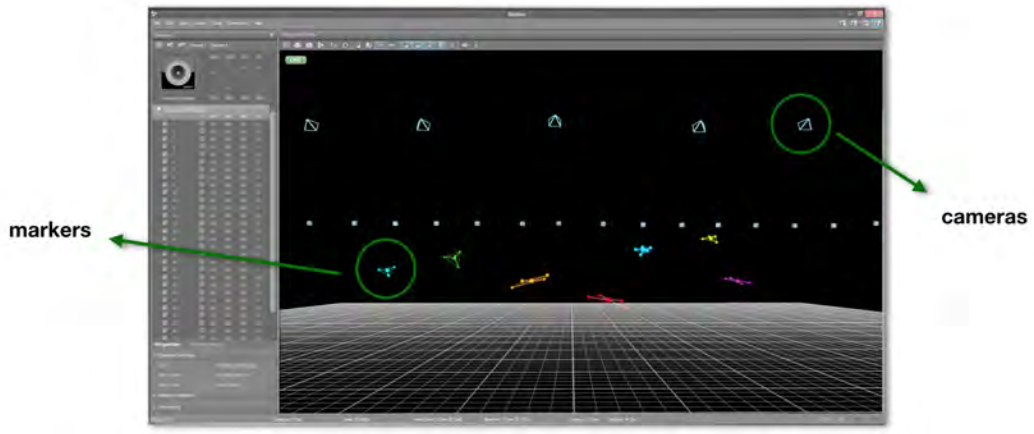


Fig. 12. Optitrack.

6.3 Generators

The Generators are programs that produce stream data.

Actor, sends / receives motion and audio of the corresponding performer;

Director, sends camera trigger events and other controls. See Fig. 13.

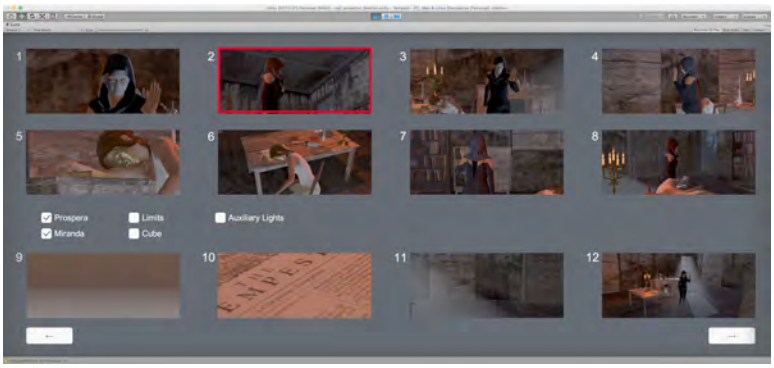


Fig. 13. Director Camera Interface.

Audience Participant, receives / sends motion of individuals from the public.

6.4 Receivers

Receivers are programs that consume stream data.

Projector, receives all stream data (motion, audio, triggers) to render the Cinema presentation in real-time;

Audience Viewer, receives stream data to render a VR presentation.

6.5 Content

In the Content category there are programs that manipulate the Timeline data.

Recorder, creates the *ks* file from the data streams;

Player, decodes and streams the *ks* file to the network. See Fig. 14.

Fig. 14. Recorder / Player.

6.6 Production

Production programs allow content generation and manipulation,

Editor, makes modifications to a *ks* file;

Blocking Planner, facilitates the definition of the actors movements in the stage. See Fig. 15.

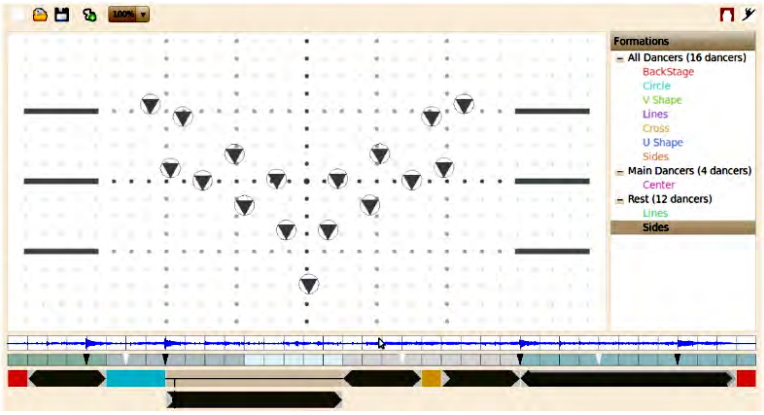


Fig. 15. Choreographics Planner.

Set / Stage Modeler, help the construction and lay-out of the elements of a scene.

A RELATED WORK

The VR Kino+Theater platform is the result of research from the VISGRAF Lab in the areas of Virtual Reality, Augmented Reality, Motion Capture, Dance and Music.

Some of the related previous projects include:

- New Realities [9]
- 3D Table [4]
- Blender Previz [10]
- Dance Louise [8]
- Choerographics [5]
- Analivia [7]
- DMPM [6]

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