"From Cinematic High Frame Rate to Immersive Cinema"

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Opening — The Question of Motion

Ladies and gentlemen, distinguished guests, fellow artists and technologists,

For nearly three decades, I have been obsessed with a single question: *how does motion feel?*

Not how it looks on paper, not how it measures on an oscilloscope — but how it *feels*, inside the human body, when light moves across a screen and our ancient visual cortex decides whether what it sees is real.

I am a technologist. I work in silicon and algorithms. But the problem I work on is fundamentally a humanist one: what does it mean to truly *see* motion? And how can cinema — the art form that conjures worlds from light — meet the full perceptual potential of the human being sitting in the dark?

Part I — The Birth of TrueCut Motion: Science in Service of Art

Twenty-six years ago, Pixelworks began developing what we now call TrueCut Motion technology. At its heart, it is a *motion appearance model* — a computational framework that models not just what a camera captures, but how a human visual system perceives the movement in that image.

The story of why this matters begins with a paradox. Cinema has always been shot at 24 frames per second — a convention born partly from economics, partly from the limitations of early film stock. And yet, for nearly a century, audiences around the world have accepted this as the language of cinematic truth. The slight blur, the stroboscopic flicker in fast pans, the motion cadence of 24fps — these became not defects, but *aesthetics*. They became part of what films *feel* like.

Then James Cameron came along.

When *Avatar: The Way of Water* introduced audiences to 48 frames per second in select theaters, the reaction was visceral — and divided. Some viewers felt transported into a world more vivid and present than any cinema had offered before. Others felt a strange alienation: it looked "too real," too much like a soap opera, too little like the movies they had grown up loving.

This is not simply a technical problem. It is an aesthetic and perceptual one. The question is not *can* we render 48 frames per second — it is *when should we*, *how much of the image should*

move at high frame rate, and *how do we preserve the emotional and artistic intent of the filmmaker* when we do?

Our motion appearance model was built to answer exactly this question. It allows filmmakers to control motion perception with surgical precision — selectively applying high frame rate rendering to action sequences while preserving the cinematic look of slower, more emotional scenes.

The films that trusted us with this work speak for themselves: *Avatar: The Way of Water*, *The Wild Robot*, *The Bad Guys*, *Argylle*, *Godzilla x Kong: The New Empire*, *Kung Fu Panda 4*. And on the Chinese side, a growing number of action productions where the kinetic energy of the genre could finally be seen with full clarity, without the motion blur and judder that had always stolen something from the experience.

And we went back in time: remastering the original *Avatar* and *Titanic* in 48fps for Dolby Cinema — giving audiences a chance to experience those classics in a form their creators could only dream of when they first made them.

Part II — A Moment in the Theater

I want to tell you about a moment that I think of often when people ask me what this work is *for*.

We were in the theater, deep in the process of remastering the original *Avatar* for 48fps Dolby Cinema. The scene we were working on is one most of you will remember: Jake Sully, newly arrived on Pandora and separated from his team, is attacked at night by a pack of viperwolves. He tries to defend himself with a flaming branch — alone, frightened, overwhelmed — while these creatures close in from every direction.

In the original 24fps version, as in most action sequences shot at standard frame rate, there was a trade-off built into every frame. The wolves were fast and ferocious — but in the motion blur and judder of 24fps, you could not fully see them. You felt the chaos of the attack. But the faces of the animals — the specific, terrifying intelligence in their eyes, the anatomy of their aggression — was lost to the blur.

Jon Landau, the legendary producer of *Avatar* and one of the great creative forces in modern cinema, came to the theater while we were working. He watched the sequence in TrueCut Motion. And afterward, he told us something I have never forgotten.

He said that James Cameron and the creative team were seeing this scene, truly seeing it, for the first time. For the first time, they could see the faces of the wolves — could read the ferocity and the intention in their expressions — and at the same time, the fierce, kinetic violence of the attack was exactly as the director had always meant it to be. Not softened. Not slowed. Not made pretty. But *clear*. The motion was fierce and the faces were visible, simultaneously, in the same frame.

That is what this technology is for. Not to make films look like television. Not to impose a hyperreal aesthetic on stories that don't want it. But to honor the filmmaker's intention — to give back to the image what the technical limitations of 24fps have always taken away.

Jon Landau passed away in 2024. I think of that afternoon in the theater whenever I am asked why motion perception matters. He understood, instinctively, what we had been trying to prove for years: that seeing clearly is not a technical achievement. It is an artistic one.

Part III — The Perceptual Science Beneath the Art

To understand why this matters for the future, let me take you briefly into the science.

The human visual system did not evolve to watch movies. It evolved to track predators across a savanna, to catch a thrown object, to read the micro-expressions on a face across a campfire. It is extraordinarily sensitive to motion — and it is extraordinarily critical when motion feels *wrong*.

Our motion appearance model is grounded in this biology. We model the relationship between frame rate, camera motion, object motion, and the perceptual qualities that emerge — judder, blur, strobing, hyperrealism. We can predict, for any given shot, how a viewer's visual cortex will respond to motion rendered at different frame rates.

What we discovered, over years of study and iteration, is that motion perception is not a single variable — it is a *space*. The same camera pan that feels smooth and naturalistic at 48fps in an IMAX action sequence can feel alienating and inappropriate at 48fps in an intimate emotional scene. The "right" frame rate is not a number — it is a *relationship* between the image, the scene, the story, and the viewer's nervous system.

This is where science and art become indistinguishable. The filmmaker's intuition about what "feels right" is, in fact, an implicit model of human perception. Our work makes that model explicit, computational, and controllable.

Part IV — The Immersive Perceptual Gap

But cinema is transforming. The rectangle on the wall — even the magnificent rectangle of an IMAX screen — is giving way to something entirely new: immersive environments. VR headsets. Dome theaters. 270-degree curved screens. Experiences in which the viewer is not *looking at* a world, but *standing inside* one.

And here, the stakes become far higher. Because in immersive environments, the relationship between viewer and image changes in four fundamental ways — and I want to describe these not as engineering specifications, but as *perceptual realities*.

First: the field of view expands dramatically. A standard cinema screen occupies roughly 40 to 60 degrees of your visual field. A VR headset can subtend 90 to 200 degrees. This matters because the perception of motion — of jitter, of stutter — scales with angular velocity on the retina. When your field of view is wide, a camera pan that would be imperceptible in a theater becomes a violent, nauseating lurch. The immersive screen does not forgive motion artifacts that cinema politely ignores.

Second: in VR, your body participates. In a cinema, you sit still and watch. In VR, you move — and the image moves with you, updating in response to your head's rotation through space. This engages a system called the Vestibulo-Ocular Reflex — the ancient neural circuitry that coordinates your eyes with your inner ear to keep the world stable when your body moves. When the image update lags behind your head movement, or when motion artifacts disrupt the expected correspondence between body and image, the result is not discomfort — it is sickness. Visually Induced Motion Sickness is a physiological response, not a preference. It is the body's alarm system signaling that something is deeply wrong.

Third: latency becomes a safety parameter. In cinema, frame rate is an aesthetic choice. In VR, it is a physiological constraint. The total delay from head movement to display update must not exceed 20 milliseconds to prevent cybersickness. Frame rate is not separate from latency — it sets the floor on how quickly the system can respond. At 24fps, the minimum possible latency is approximately 42 milliseconds — more than twice the threshold for comfort. This is why immersive cinema requires fundamentally different motion engineering, not simply higher frame rates.

Fourth: stereo vision adds new dimensions of complexity. In S3D and VR content, the left and right eyes receive slightly different images — and the brain fuses them to construct depth. But motion artifacts interact with stereoscopic disparity in ways that monocular models cannot predict. A jitter that is barely visible in a flat image can become a disturbing and disorienting oscillation in stereo, because the two eyes interpret it differently. Our models must account for the full binocular experience.

Together, these four factors define what I call **the Immersive Perceptual Gap** — the chasm between the motion quality that immersive environments demand, and what existing cinematic and display technology delivers.

Filling this gap is the central challenge of our work today.

Part V — Toward an Aesthetic of Immersive Presence

I want to step back from the engineering for a moment — because this conference is asking a deeper question.

The theme of this dialogue is the transformation of human perception in the digital age. It asks how scientific rationality and artistic sensibility converge — and how art, in turn, feeds back into technological innovation.

I believe the immersive cinema project is a perfect embodiment of this dialogue.

The science tells us what the body can tolerate, and what it cannot. The physiology of the vestibulo-ocular reflex is not negotiable — it is the voice of hundreds of millions of years of evolution. But within those constraints, there is an enormous space of artistic possibility.

What does *presence* feel like? What is the aesthetics of immersion? When a viewer stands inside a VR world, surrounded on all sides, with their body participating in the experience — what should that feel like? Should it feel like reality? Or should it feel like something new — a mode of experience that only art can create, that has no precedent in the physical world?

I think the answer is: both, and neither. The goal of immersive cinema is not simulation. It is not the replacement of the physical world with a digital one. It is something more interesting: the creation of *perceptual spaces* that could not exist in nature, but that feel, to the body, completely and undeniably real.

This is the frontier that our motion appearance model for immersive environments is designed to explore. We are building the technical foundation — the frame rate support systems, the latency management, the stereoscopic motion modeling — not as ends in themselves, but as the instruments that will allow artists to compose in a new perceptual dimension.

Just as the invention of equal temperament gave composers access to all 24 major and minor keys — enabling Bach and Beethoven and eventually jazz and the music of our own time — the engineering of motion perception gives the cinema artists of the coming generation access to a new palette. Not just light and color and sound, but *presence itself* — the feeling of being inside a world.

Closing — An Invitation

Ladies and gentlemen, I began my career studying how motion *feels*. I hope to end it — many years from now — having helped create the tools that allow artists to *compose* with feeling itself.

The journey from 24fps cinema to immersive presence is not a technological story. It is a story about what it means to be a human being encountering a moving image — about the ancient circuitry in our bodies that responds to light and motion, about the artists who have spent a century learning to speak to that circuitry, and about the scientists and engineers who are, right now, expanding the vocabulary of that language.

That afternoon in a Dolby theater, when Jon Landau told us that for the first time a filmmaker could see both the ferocity and the faces of those viperwolves — that was not a technical milestone. It was a moment of artistic clarity, made possible by science.

That is what we are building toward. For cinema. For immersive environments. For whatever comes next.

The perceptual gap is real. We intend to close it. And on the other side, I believe, lies an art form that does not yet have a name.

Thank you.