Veillance Dosimeter, inspired by body-worn radiation dosimeters, to measure exposure to inverse light

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***Abstract*—We present a system that measures veillance flux, the ability of a camera to see, as the flux propagates through space. By wearing a veillance-integrating device, individuals are given an accumulated dosage readout based on their presence or absence in the veillance field of various cameras. The dose readout can be used as a score for players in an image-capture gaming environment, and as a means to assess camera coverage in security and cinematography applications. This veillance dosimeter detects radiation of information-bearing optical sensitivity, as opposed to radiation of light energy in the opposite direction.**

I. Introduction

Recently we introduced *veillance flux* and the *veillance field*, a mathematical formulation to account for the *ability to see* as it propagates through space from a camera [1].

An intersecting web of veillance field lines and veillance flux, ordinarily hidden in the world around us, are "emitted" by various surveillance cameras, sousveillance cameras (*e.g.* body-worn cameras [2]), and embedded vision on hands-free doors, faucets, and lighting systems.

The first measurements of the veillance field employed a laser-scanning method, to quantify the ability to see, and its absorption, reflection and refraction as it propagated through space from cameras [1]. The veillance field also exists for sound wave sensing, atmospheric pollution sensing, weather and climate sensing, fluid thermal sensing, *etc.* [1].

In this work, we present a portable system that measures veillance flux interception, as a score for players in a gaming environment, and as a means to assess camera coverage in security and cinematography applications. By measuring "sight", it allows individuals to experience and measure that which is invisible. Participants can sense the information-bearing sensitivity to light as it propagates through space.

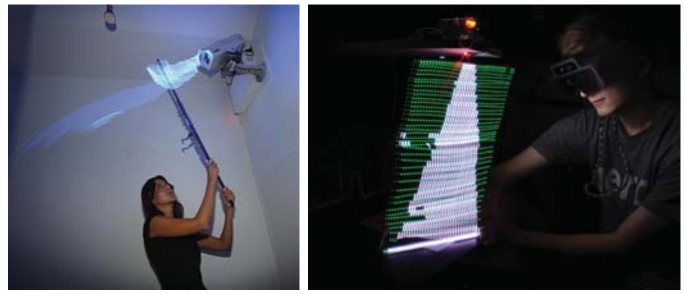

Fig. 1. Computer vision made visible: Illuminating the veillance field [1] from cameras, by combining veillametrics [1] with abakography [4] using a long-exposure photograph and time-varying stimulation of LEDs.

II. Seeing and Measuring Sight

We set out to create the equivalent of a radiation dosimeter [3] as used in the nuclear industry, as a body-worn patch or device to integrate total radiation dose over a period of time.

However, our veillance dosimeter is *sensitive to the sensitivity to radiation* (i.e. information-bearing reverse optics).

Firstly, one method to "see sight" we have designed uses a video feedback loop, in a "video bug sweeper", analogous to the audio bug sweepers used to detect hidden microphones. An audio bug sweeper demodulates radio signals to baseband

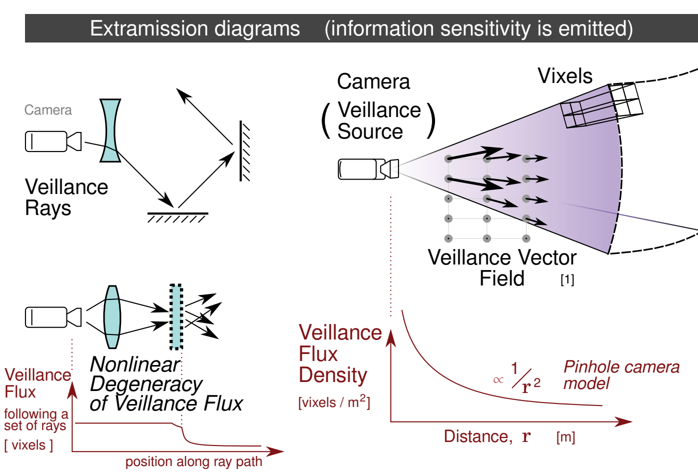

Fig. 2. Extramissive diagrams of veillance propagation.

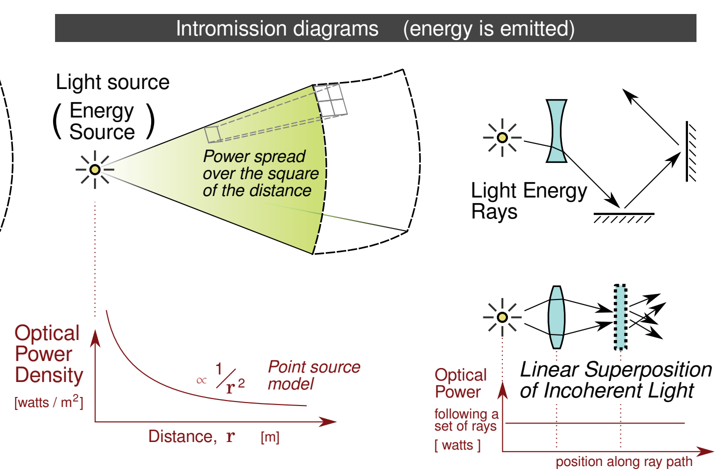

Fig. 3. Intromissive diagrams of light propagation.

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audio, amplifies the signal, and reproduces it in a loudspeaker to induce feedback and thus "squeal" in the presence of a bug. However, our video bug sweeper uses feedback of video intercepted from a surveillance camera, to control a handheld array of LEDs. Whichever LEDs are present in the camera's veillance field are detected in the video signal by an embedded microcontroller and are lit with a different colour to indicate when and where veillance is detected in real-time. However, to explain *numerical* veillance measurement, we now explore a formulation of information-bearing reverse optics.

III. Extramissive Radiation, vs. Intromissive Radiation

Figures 2 and 3 show two complementary types of radiation: the propagation of light, versus the propagation of the *sensitivity to light* through space. The veillance field and veillance flux, introduced in [1], are drawn in Fig. 2. Unlike light propagation, the veillance field and veillance flux indicate the *information-bearing capacity* of light rays traced in reverse.

Radiation, whether emitted by a light source, or emitted by a camera, follows a $1/r^2$ decay pattern. That is, the power intensity of light decreases as $1/r^2$ relative to distance r from a point source. Similarly, veillance flux density decays with distance as $1/r^2$ (in the limit of a small aperture approaching a pinhole camera). The reason for the latter is the spreading of the cross-sectional area of *vixels* [1], the spatial regions controlling each linearly independent pixel, shown in Fig. 2.

This dual inverse-square law has the interesting effect that if a radiative sensor is coupled with an auxiliary radiative power source, then a separate veillance detector can detect veillance flux density in proportion to the local intensity of the auxiliary power source (as long an optical field does not cause vixel degeneracy [1], illustrated in Fig. 5f). Thus, one simple implementation of a veillance sensor is to affix an infrared source to a camera, with a pulse coding scheme, and remotely decode the infrared light and detect its power at the location under test. However, this method does not account for vixel degeneracy or the nonlinear effects of camera saturation. A feedback method, using LASER or LED array stimulation, and a veillance degeneracy analysis algorithm [1], better accounts for vixel absorption and loss of linear independence as veillance reflects and scatters in a complex optical environment. We now examine how measuring veillance over a region of space relates to the veillance field and veillance flux.

The *veillance vector field*, $\vec{V}$, is defined as a vector field everywhere pointing in the direction of veillance radiation, and with its magnitude proportional to the density of vixels (spatial extent controlling one pixel) [1]. The veillance vector field represents the spatial behaviour of the ability to see. It can further be generalized as a vector set field for spatial regions where veillance rays intersect.

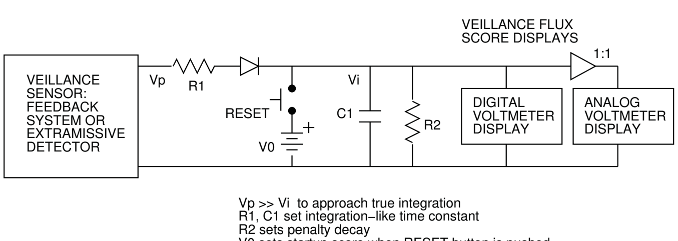

Fig. 4. Veillance flux integrator circuit, to create a scorekeeping dosimeter *sensitive to the sensitivity to light*.

Veillance flux, Φ_V, describes the veillance radiation impinging a surface, Ψ, integrated over infinitesimal segment normals $\vec{dS}$ at positions $\vec{r}$:

$$\Phi_V = \int_\Psi \vec{V}(\vec{r}) \bullet \vec{dS} \qquad (1)$$

The *veillance field* can be expressed as:

$$V(\vec{r}, \angle\vec{\chi}, d) = V(x, y, z, \theta, \phi, d) \qquad (2)$$

and is a scalar quantity that accounts for intersecting veillance rays from multiple pathways (direction $\vec{\chi}$ or angles θ and ϕ), and from multiple sensor devices (d). V is an information-bearing analogue of the 5D plenoptic function [5]. V can be measured in [vixels/sr/m^2], and its bit-rate sister quantity $\forall$ is measured in [bits/sr/m^2/s].

The intensity of the $\forall$ field indicates the **bit rate of information sensitivity, per steradian, per unit area.**

Our dosimeter gives an accumulating dose reading, measured in [bits], by aggregating $\forall$ over a macroscopic area and solid angle, and integrating over time.

IV. Veillance field integration device

Our dosimeter system measures the veillance field, sensing the capacity to see, as it radiates out of a camera and spreads, reflects, and scatters in various ways, propagating through a room or another optical space.

Veillance flux that strikes the dosimeter is time-integrated. We connected the analog output of veillance sensors described earlier to a dosimeter circuit (Fig. 4). The circuit uses a capacitor as a memory element to permit time-integration of the veillance score in the form of voltage. A readout of the user's dose is visible using voltmeter displays on the body-wearable device. A digital voltmeter allows users to observe even a slow change in dose caused by faraway cameras, or caused by standing near diffused (degenerate) reflections of veillance flux, while an optional analog voltmeter gives an at-a-glance view of the user's current total dose.

A dose-initializing reset button allows a preset initial dose reading to be charged to the integrating circuit. A discharge resistor can impose a slowly-integrated restorative force (*e.g.* no-action penalty in a game) if a user does not continue to accumulate veillance. Individuals can switch between scopophilic (desiring to be seen by a camera: the reading increases when exposed to veillance) and scopophobic (avoiding being seen by a camera: readout decreases when exposed to veillance) modes, by reversing the polarity of the circuit.

V. Veillance field from the Human Eye: Bio-veillametrics, Bio-veilluminescence

We introduce the concept of biological veillance. Measuring and visualizing veillance fields from organic senses can be accomplished with a behavior-based feedback loop. The human eye has an uneven distribution of receptor cells in the retina, so to measure veillance flux we designed a dynamic stimulus-response program which tested a user's visual-field

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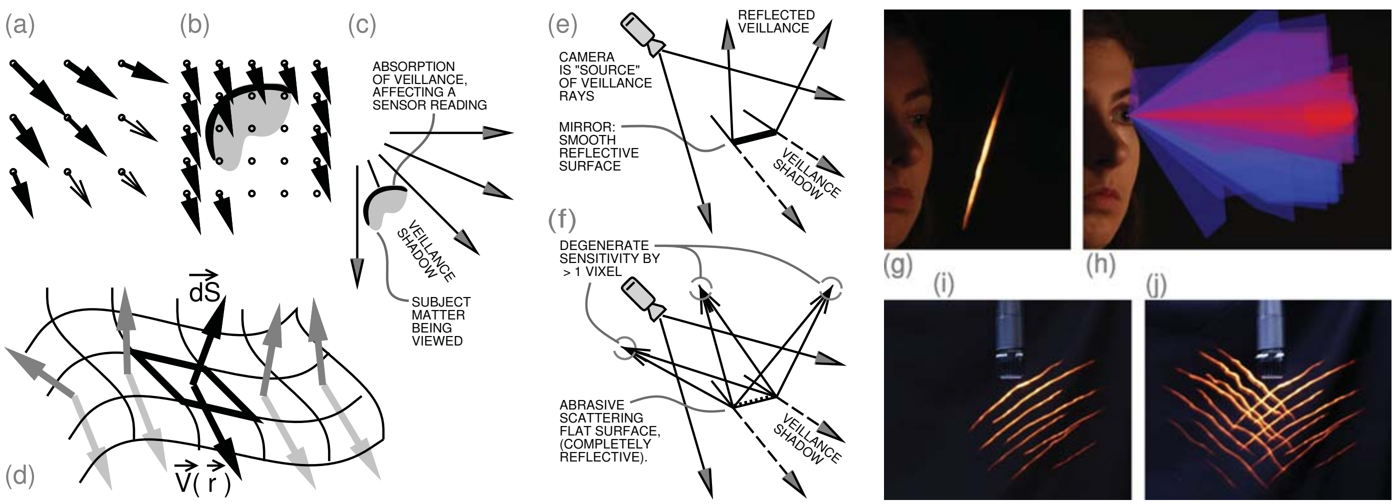

Fig. 5. **(a) The Veillance Field** represents the *capacity to sense*. Veillance field vectors can be defined at all points in space, as opposed to vixel rays (c) which trace out a tangent to propagation of the capacity to sense. Veillance field intensity at each point is proportional to the density of vixel rays (akin to the density of electric or magnetic field lines, forming a field intensity). **(b) Absorption of veillance** on the leading edge of an opaque object. A rough-surfaced reflective opaque object is an effective absorber of optical veillance, because its diffused reflection causes degeneracy in the reflected vixel rays. From the sensor's perspective, there is less unique information about reflected subject matter (other than the fact that the subject matter may be getting brighter or dimmer in total); hence the reduction in veillance (*i.e.* absorption of veillance) caused by diffused reflection of light. **(c) Vixel rays**, each associated with one vixel—the volumetric region of sensitivity for one pixel. Here, a vixel is absorbed by an object (the object is seen), and the remaining vixels are able to continue onward. **(d) Veillance flux**: Veillance impinging a 3D surface area, broken down element-by-element, where the veillance vector field is integrated over the surface to yield veillance flux. **(e) Reflected veillance rays** from a camera. **(f) Degeneracy**: Reduction in veillance by loss of uniqueness of each pixel, from reflection on a diffusely-reflective surface. This example shows that energetic optics and veillance optics are not simply converse equivalents, or time-reversed duals of each other. All light energy may be reflected, but not all unique veillance flux may be reflected. **(g) Biological veilluminescence**: Long-exposure image of a light bulb in motion, interfaced to computer; the bulb powered by pulse width modulation following a 1D slice of an offline vision test. Note the bulb has nonlinear behavior. **(h) Bio-veillametric** computer rendering of veillance flux from vision test points, with red representing max. veillance flux density in the vision test. Note the faint, semi-transparent samples, which were tested. **(i-j) AudiLuminescence** of a microphone: Time exposures of a light bulb, moved by hand, and controlled in real-time by a logarithmic analog circuit, measuring the sensitivity of a SM57 microphone to a 330Hz tone emitter coupled to the light bulb.

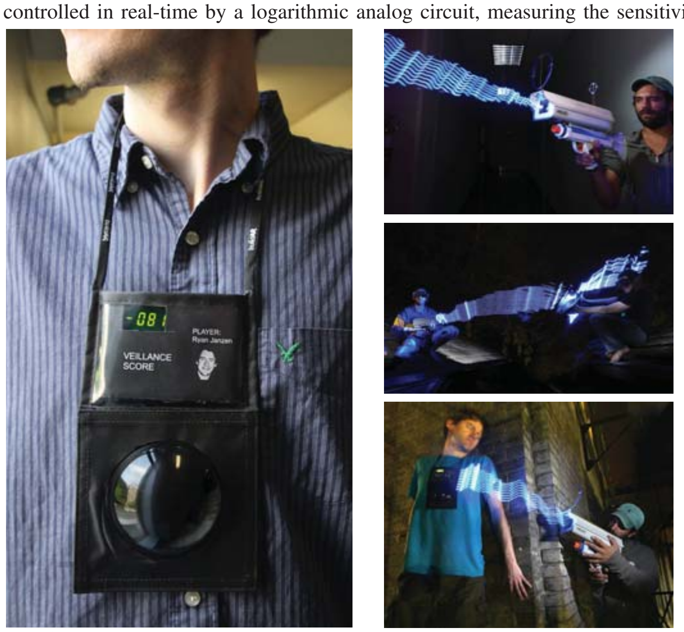

Fig. 6. (LEFT) Veillance Dosimeter. This unit is configured for scopophobic mode: negative numbers accumulate during exposure to veillance flux. The numerical dose reading is scaled down from the raw integral of ∀, proportionally, to fit within three digits of text. An attenuated dome provides space for optics to sense external veillance, plus optionally an additional camera, for individuals who "emit" veillance flux, *i.e.* who shoot video of others. *(We thank Pete Scourboutakos for aid in arranging the electronics to fit inside the neckstrap pouch, and thank Laura Bolt as test subject in Fig. 5g-h.)*
(RIGHT) Veillance flux "shot" from a camera: Pulling the trigger causes the camera to "shoot" a picture. The middle image shows veillance flux being reflected by a mirror, while in the lower image, the *ability to see* is nearly striking an individual's body-worn dosimeter. Veillance flux was made visible in these photos by combining veillametrics [1] with long-exposure abakography [4] using a video bug sweeper.

observation accuracy with short-burst stimuli at different locations on a computer screen. The system approached the just-noticeable difference of stimuli size/locations based on a user's keystokes. Veillance flux was then rendered (Fig. 5g-h).

VI. Audimetrics and AudiLuminescence

We introduce the *audimetric field*. Emissions from a microphone were visualized in Fig. 5i-j. The Latin prefix "audi" is used here for a field of "listening" as opposed to "soni-" for "sound". That is, we are not merely visualizing emitted sound waves, but are instead visualizing emissions of *sensitivity* to sound waves. This system exhibits a different class of veillance field, based not on vixel density (since only one vixel is created by one microphone), but based on a *veillance-to-noise ratio (VNR)*, which is an extramissive analogue to signal-to-noise ratio (SNR). We can thereby measure extramissive fields, sensing fields, and sense-space for waves and diffusive sensing.

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