100 Years Light-Field

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Photoshop

March 1908 - March 2008
“Directional Imaging”

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What is **Light-Field**?
What is **Light-Field** or **directional** imaging?

4D radiance
What is Light-Field or directional display?
What could we do if we didn’t throw away directional info at each pixel?

We are talking about 4D images, not cheap stereo glasses.

- Focus the image after the fact. No more blurry pictures!
- Control the focus of every pixel with a “focus brush”
- Move the camera after the fact
- Select objects automatically – based on depth information
- Insert objects into a scene – with proper occlusion based on depth
Lippmann 1908
About Lippmann

Nobel Laureate for Color Photography
About Lippmann

Lippmann was the thesis advisor of Marie Curie
Integral Photographs (Light-Field Photography) 1908

Lippmann film
(Light-Field film)
Light-Field film

Deriving the lens curvature equation for a section of Lippmann’s film “Light-Field film”

\[
\frac{\sin \alpha}{\sin \beta} = n
\]

\[
\delta = \alpha - \beta = \alpha \left(1 - \frac{1}{n}\right) = \alpha \frac{n - 1}{n}
\]

\[
(R + r)\delta = x
\]

\[
(R + r) \frac{x}{r} \frac{n - 1}{n} = x
\]

\[
\frac{R}{r} + 1 = \frac{n}{n - 1}
\]

\[
\frac{R}{r} = \frac{1}{n - 1}
\]

\[
\frac{r}{R} = n - 1
\]
Sokolov 1911
Ives 1930 (Lenticulars)
Ives 1930 (Large Lens)
Coffey 1935 (F/# matching)
Ivanov (1948) 2 million lenslets
Gruetzner (1952) commercial camera
Chutjian 1968 (First Digital Light-Field)

This was done before the first digital camera (Kodak 1975)!
(Note: The first digital camera had 0.01 Megapixels; the first digital lightfield camera - 0.1 Megapixels)
Dudnikov 1970 - 1982 (detailed research)
Ivars 1988 (Diffraction lenses)
Adelson 1991 (Plenoptic Function)
Adelson 1992 (Plenoptic Camera)

Designed with the idea to solve *Computer Vision* problems
Levoy 1996 (Light Field Rendering)
Levoy 1996 (Light Field Rendering)
Isaksen 2000 (Light Field “Reparametrization”)

$D_{s,t}$

$(u,v)$

$r=(s,t,u,v)=(s,t,f,g)_F$

$(f,g)_F$

data cameras

camera surface $C$

focal surface $F$

Left Eye

Right Eye

Lens Array

$C$

$F$

Object
Isaksen 2000 (Light Field “Reparametrization”)
Billy Chen 2002 (Autostereoscopic Display)
Ng 2005 (Hand-Held Plenoptic Camera)

Note: The first digital camera (1975) produced image 0.01 Megapixels. The first digital lightfield camera (2005) produced image 0.1 Megapixels. Ren is 10 times better!
Ng 2005 (Fourier Slice Refocusing)

\[
\begin{align*}
L_F & \quad \xrightarrow{\mathcal{F}^4} \quad O(n^4 \log n) \\
\mathcal{P}_\alpha & \quad [O(n^4)] \\
E_{\alpha} & \quad \xrightarrow{\mathcal{F}^2} \quad O(n^2 \log n) \\
\mathcal{L}_F & \quad \xrightarrow{\mathcal{F}^4} \quad O(n^4 \log n) \\
\mathcal{P}_\alpha & \quad [O(n^2)] \\
\mathcal{E}_{\alpha} & \quad \text{Fourier-space Photograph Synthesis}
\end{align*}
\]
Fife 2008 ("Light-Field" Chip)
For 100 Years Lippmann’s idea has been **Possible**…

Now Radiance Photography is **Practical**!