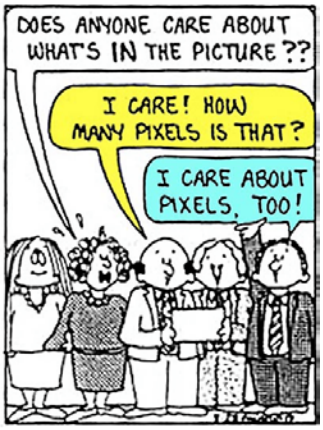
'Pixel':
A Brief History

Richard F. Lyon
Chief Scientist, Foveon, Inc.,
Spouse Member of the ACM,
& Fellow of the IEEE



What is a pixel?

Where does the word *'pixel'* come from?

Why do I care?

'Pixel' = 'Picture Element' — since 1969

ONLINE ETYMOLOGY DICTIONARY

pixel
1969, coined to describe the photographic elements of a television image, from *pix* (1932 abbreviation of *pictures*, coined by *"Variety"* headline writers) + *el(ement)*.


Kaiserliches Patentamt

KAISERLICHES PATENTAMT

PATENTSCHRIFT

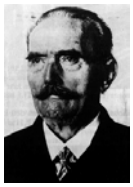
— № 30105 —

PAUL NIPKOW in BERLIN.

Elektrisches Teleskop.

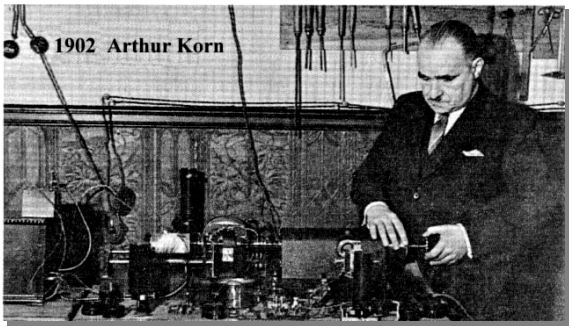
Paul Nipkow
1884

'Bildpunkte'
(picture points)



Arthur Korn

1904 *Elektrische Fernphotographie:*
'Punkt … ist streng genommen ein kleines **Flächenelement**…'



'Picture Elements' auf Deutsch:

'Bildelemente'


Schröter invented interlaced scanning

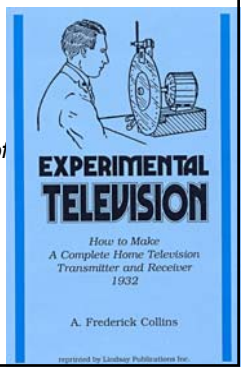
- Paul Nipkow 1884 "Bildpunkte"
- Arthur Korn 1904 "Flächenelement"
- Gustav Eichhorn of Zürich, **1926**, "*Wetterfunk Bildfunk Television (Drahtloses Fernsehen)*": "die Tönung der **Bildelemente**," "**Bild**punkte des Rasterbildes," "Flächen**elementen**"
- Fritz Schröter, 1932, "**Rasterelementen**," "Rasterzahl," "Punkten"
- Manfred von Ardenne, 1933, "Durchmesser eines **Bildelements**," "Bildelementdurchmessers," "Bildpunkte"


Von Ardenne developed CRT displays

ixels and Me: a journey of historical

First 'Picture Element' Publications

- 1927 *Wireless World* mag. (according to William Safire's "On Language" column)
- 1929 H. Horton Sheldon & Edgar Norman Grisewood, *Television: Present Methods of Picture Transmission*
- 1932 A. Frederick Collins, *Experimental Television: How to Make A Complete Home Television Transmitter and Receiver*



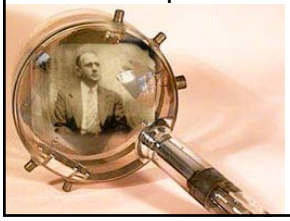
RCA: Zworykin, Kell, Engstrom, …

'33 **'picture element'** used separately by Vladimir K. Zworykin, Raymond D. Kell, and Elmer "Shorty" Engstrom.

'37 Five papers: Alfred Goldsmith, C. E. Burnett, R. R. Beal, Harley Iams, Albert Rose

'37 Zworykin **"The picture element is a purely fictitious concept when applied to the mosaic."**

'38 **'theoretical picture element'** I. G. Maloff and D. W. Epstein



Last RCA'picture elements':
'46, '48 Albert Rose
'48 Otto Shade
'49 Janes, Johnson, and Moore

Vladimir K. Zworykin and his 'iconoscope'

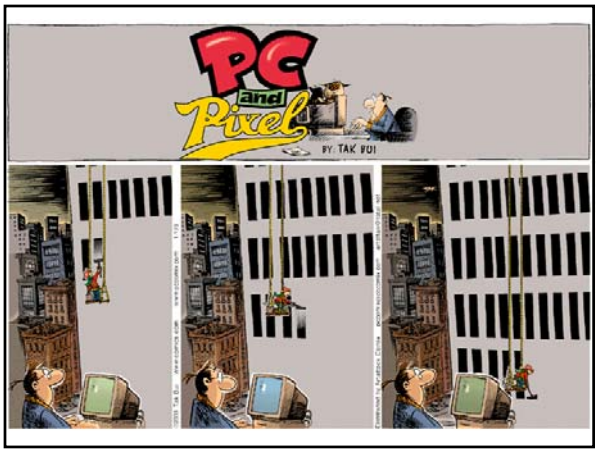
'Picture Elements' in the 1960s — surprisingly few

- **Lawrence G. Roberts** 1961, 1962
  - Dithering and Playboy pix
- Béla Julesz 1962
- Al Oppenheim, Ron Schafer, and Tom Stockham 1968
- L. R. Malling and J. Denton Allen 1966
- Robert B. Leighton et al 1967
- Azriel Rosenfeld 1969
- Andrew T. Young 1969
- G. E. Forsen 1969
- Paul K. Weimer 1969

William F. Schreiber and 'Pel'

MIT Prof. Schreiber's secretary Claire Kay coined 'pel' for him in 1964 (alternative to German BP), published 1967 in Proc. IEEE

Schreiber, Troxel, and Seitz didn't use 'pel' nor 'pixel' in their 1969 paper on wirephoto standards converter



Pixel-like Terms

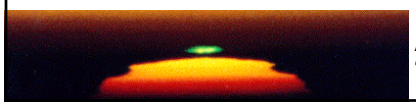
- point
- sample
- spot
- position
- cell
- dot
- bit
- element
- picture element
- pel
- p. e.
- area element
- image element
- raster element
- matrix element
- resolution element
- video element
- picture point
- raster point
- digital sample
- gray value
- sample spot
- beam spot size
- point of the picture
- mass of dots
- elemental area of the picture
- elemental area of said image
- elemental tone value
- a mosaic of selenium cells
- a great number of small parts
- thousands of little squares
- little areas of varying brilliance
- optical fragment
- photosite
- photoelement
- photodiode
- photodetector
- photosensor

ixels and Me: a journey of historical

Mariner 6 (to Mars)

1969 Article Cited by O.E.D.

- Robert Leighton, Norman Horowitz, Alan Herriman, **Andrew Young**, Bradford Smith, Merton Davies, Conway B. Leovy, "Mariner 6 Television Pictures: First Report," *Science*, Aug. 15, 1969.
- **"resolution elements ('pixels')"**
- Young: "I thought *pixel* was a **vile neologism**, and tried to avoid it myself. It was in use by the guys in the Image Processing Lab."



Andrew T. Young's "Green Flash"

The Billingsley Connection

Carver Mead
Foveon/Caltech

Jerry Solomon
Caltech/JPL

Dick Lyon
Foveon

Fred Billingsley
JPL

Keith McFarland
Link Division of General Precision, Palo Alto

Fred told Jerry he got 'pixel' from a subcontractor: Link of Palo Alto.

'Pixel' in the 1960s

1965 Fred C. Billingsley (in two different SPIE workshops)

1966, 1967 Keith E. McFarland, Link Div. of Gen. Precision, subcontractor, equipment manuals

1968 Charles Fernald case study on McFarland's Video-Film Converter ('pizel')

1969 Leighton et al. Science article cited by O.E.D.

1969, 1970 Robert F. Rice internal JPL memos, (the first outside the Image Processing Lab)

1970 T. C. Rindfleisch et al., external symposium on astronomical uses of TV image sensors

1970 G. Edward Danielson, Jr, same symposium

Billingsley's first 1965 'Pixel' "Digital Video Processing at JPL"

back to real time and there are zero time base displacement errors. Since the information band-width goes to 200 KC, by the sampling theorem, we must sample at least 400,000 samples per second. We have chosen to sample at a 500 KC rate and we define each one of these samples as a picture element or a pixel.

We have sampled each pixel with 6-bit accuracy which is commensurate with the signal/noise ratio and the data accuracy. This is also an optimum sample size from the viewpoint of digital computation since it fits digital computer words and also fits the standard digital tape format.

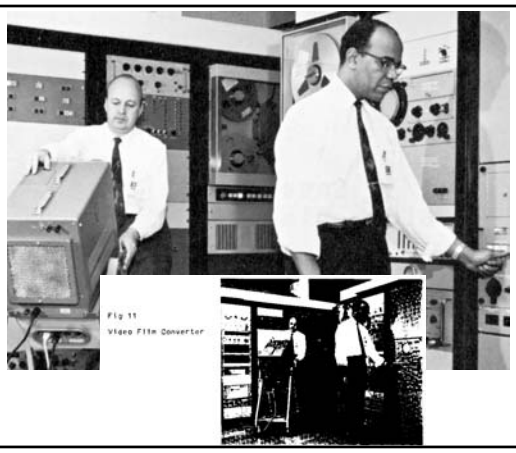


Fig 11
Video Film Converter

1971 — 'Pixel' Escapes into the Wild

- Robert F. Rice & James R. Plaunt (JPL), ***IEEE Trans-Comm.*** article
- NASA SP-263, *The Mariner 6 and 7 Pictures of Mars*
- Raimo Bakis, Michael A. Wesley, and **Peter M. Will** (IBM), Willow Run Lab. Remote Sensing Workshop
- Peter A. Franaszek, David D. Grossman, and **Peter M. Will** (IBM), U.S. patent application
- Lynn H. Quam, Stanford, dissertation

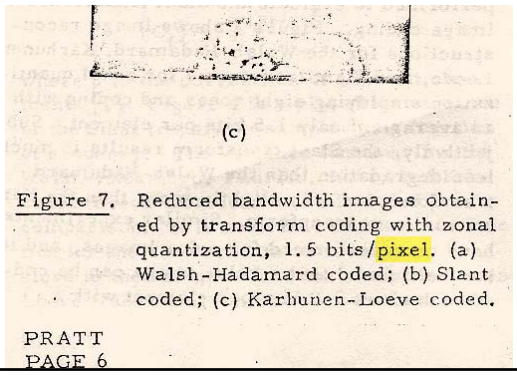
ixels and Me: a journey of historical

Few 'Pixel' Publications 1972–75

Wen-Hsiung Chen — 1973 dissertation

- Univ. Missouri at Columbia 1972
  (Degroot, Hall, Sutton, Lodwick, & Dwyer)
- USC 1972–75 (Pratt, Welch, & Chen)
- CMU 1973–75 (Rubin)
- NC State 1974 (Eastman & Stoudhammer)
- Stanford 1974 (Sobel)
- Fairchild 1974 (Dyck & Jack)
- Purdue 1975 (Wintz)
- SUNY (Albany **and** Buffalo) 1975
  (A. K. Jain, Alvord & Quinn, Herman, Lent & Lutz)
- Scientific American 1975 (Gordon, Herman, & Johnson)

Pratt, Chen, & Welch 1972

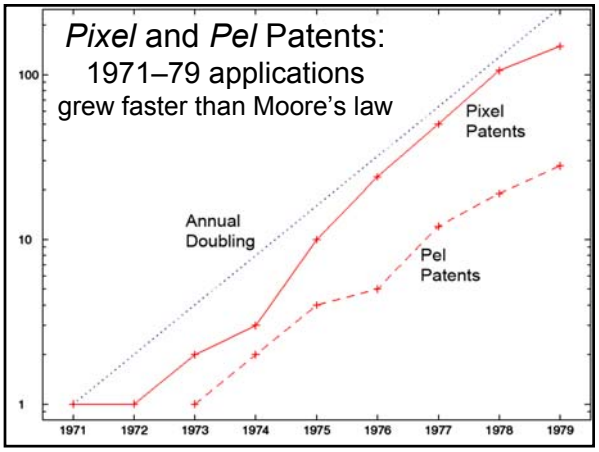


(c)

Figure 7. Reduced bandwidth images obtained by transform coding with zonal quantization, 1.5 bits/pixel. (a) Walsh-Hadamard coded; (b) Slant coded; (c) Karhunen-Loeve coded.

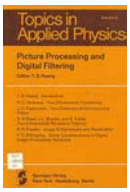
PRATT
PAGE 6

Pixel and *Pel* Patents: 1971–79 applications grew faster than Moore's law



Technical Books with 'Pixel', 1975–79

- '75 Carlo Séquin and Michael Tompsett, *Charge Transfer Devices* (Dyck & Jack figure only)
- '75 T. S. Huang, *Picture Processing and Digital Filtering* (Billingsley chapter only)
- '76 Azriel Rosenfeld, revised, *Picture Processing by Computer*
- '77 Raphael C. Gonzalez and Paul Wintz, *Digital Image Processing*
- '78 William K. Pratt, *Digital Image Processing*
- '79 Ken Castleman, *Digital Image Processing* ("to 'Uncle Bob' Nathan, pioneering pixel pusher")
- '79 Newman & Sproull, *Interactive Computer Graphics*, 2nd edition (not in 1973 1st edition)



'Pixel' in Paper Titles,1981–84

- '81 "**Pixel**-Planes: A VLSI-Oriented Design for a Raster Graphics Engine," Henry Fuchs & John Poulton, *VLSI Design*
- '82 "ACM president's letter: **Pixel** Art," Adele Goldberg, Robert Flegal, *Comm. ACM*

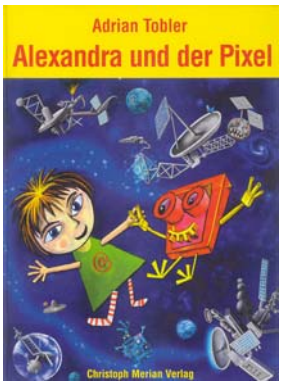

scanner designed by Joseph Malcson. The scanner samples gray levels two Forms, a source and a destination; pixels are copied out of the

Communications of the ACM December 1982 Volume 25 Number 12

- '84 "A line transfer color image sensor with 576x462 **pixels**," Berger et al., *Proc. ISSCC*
- '84 "An analytic visible surface algorithm for independent **pixel** processing," Edwin Catmull, *SIGGRAPH*

'Pixel' in Book Titles, 1985–86, & 2000

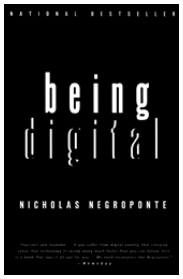
- '85 *Inside MacPaint: Sailing Through the Sea of Fatbits on a Single-**Pixel** Raft*, Jeffrey S. Young
- '85 *Mr. **Pixels** Computer Program*, **Pixel** Works
- '86 *From **Pixels** to Predicates*, Sandy Pentland.



ixels and Me: a journey of historical

Nicholas Negroponte, *Being Digital*, 1995

- After discussing Ivan Sutherland's work, Negroponte states: **"The computer graphics community invented the term 'pixel'."**
- But the first SIGGRAPH papers containing 'pixel' were in 1976 — by Negroponte & Pangaro, among others…



No 'Pixel' at Utah

- University of Utah and Evans & Sutherland computer graphics people used "raster elements" and other terms
- "Picture elements" were points, lines, polygons, etc.
- First publication with 'pixel' ***after leaving Utah:***
- First dissertation with 'pixel' was Tom Stockham's student Olivier Faugeras, 1976.

Alan Kay
Jim Clark
John Warnock
Martin Newell
Jim Blinn
Chuck Seitz
Ivan Sutherland
Bob Sproull
Raphael Rom
Lance Williams
Ed Catmull
Frank Crow
William Newman
Patrick Baudelaire
Henry Fuchs
Henri Gouraud
Nolan Bushnell
Brian Barsky

'Picture Element' as a unit of sensor hardware

1969 P. K. Weimer et al. of RCA: "the array must contain hundreds of thousands of **picture elements**"

1976 P. L. P. Dillon et al. of Kodak: "**picture elements**" in a "CFA" **color** filter mosaic sensor

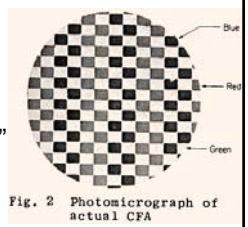


Fig. 2 Photomicrograph of actual CFA

'Pixel' as a unit of sensor hardware

'75 Donald R. Lampe and Marvin H. White, Westinghouse patent: "Such a sensor arrangement is termed a ***pixel pair***"

'80 Richard F. Lyon, Xerox Optical Mouse "**pixel** layout"

'82 Aoki et al. of Hitachi, '**pixel**' as individual single-color element of a filter-mosaic **color** image sensor

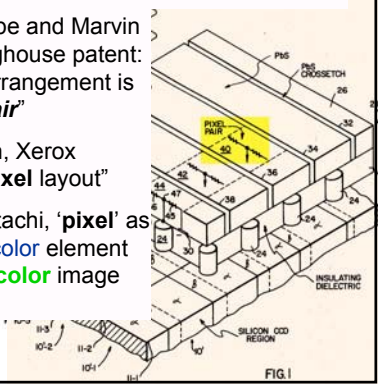
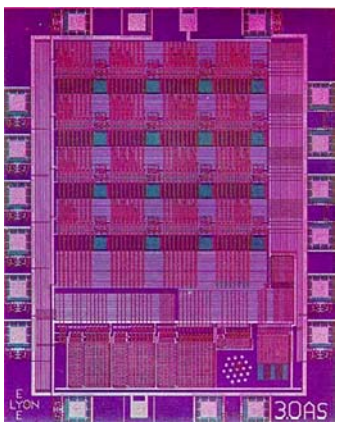


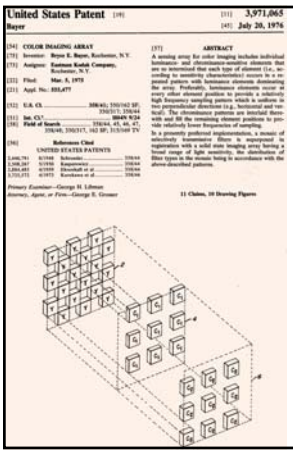
FIG. 1

1980 "Lyon Eye" Optical Mouse

"The guts of each imager **pixel** (subcircuit or cell) is therefore a dynamic node, a transistor to 'reset' it high and then isolate it, and an 'inverter' circuit to sense the voltage of the node and communicate it out to other circuits."

Photo on Smithsonian website



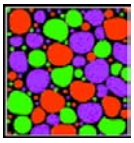


1975: Bryce Bayer's "luminance- and chrominance-sensitive elements"

unlike Dillon 1976, and Aoki 1982, and everyone today

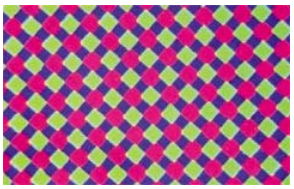
ixels and Me: a journey of historical

Early Color Filter Arrays



1904: Autochrome, Lumière brothers — Potato starch as color filter mosaic: Potato Elements?

Paget Mosaic — Used by Zworykin, 1925 Color TV Patent



Megapixel Cameras:

1991 Kodak/Nikon DCS 100
1994 Kodak/Nikon DCS 200
1995 Kodak/Canon DCS 3

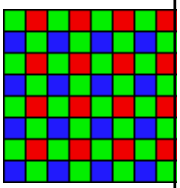
CCD *containing* 1.3 megapixels?

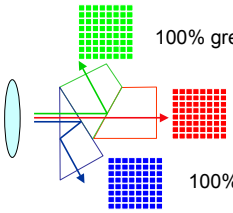
with a high density area CCD containing 1.3 megapixels.

'Pixel Sensors' Just Sense Light

So why not use all the light?

50% green
25% red
25% blue



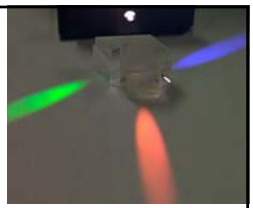


100% green

100% red

100% blue

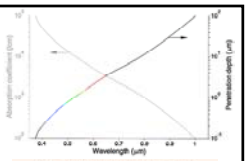
Foveon Prism Cameras

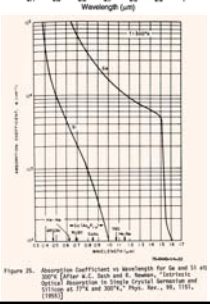


Absorption Coefficient vs. Wavelength

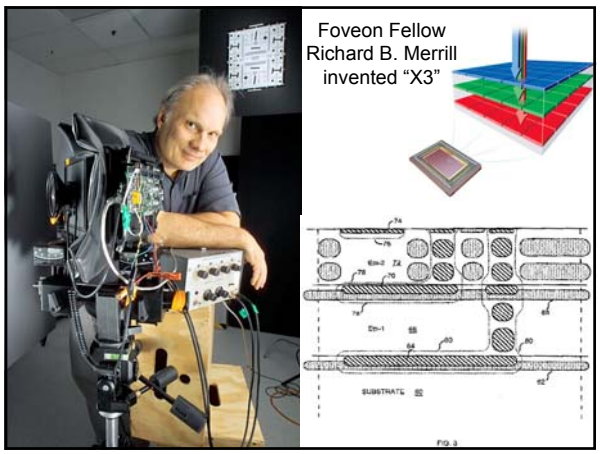
from Theuwissen 1995,
from M. H. White 1976,
from Dash & Newman 1955

Marvin H. White at Lehigh Univ.
(the 'pixel pair' guy)





ixels and Me: a journey of historical



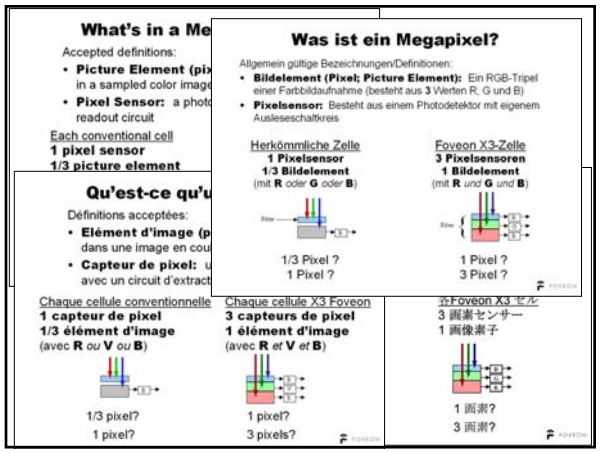
What’s in a Megapixel?

Accepted definitions:

- **Picture Element (pixel):** an RGB triple in a sampled color image
- **Pixel Sensor:** a photodetector with a readout circuit

Each conventional cell	Each Foveon X3 cell
1 pixel sensor	**3 pixel sensors**
1/3 picture element	**1 picture element**
(with **R** *or* **G** *or* **B**)	(with **R** *and* **G** *and* **B**)
1/3 pixel?	1 pixel?
1 pixel?	3 pixels?

FOVEON



3.4 MP File from
10.2 MP Camera

— Resolution to
Spare

ixels and Me: a journey of historical

International Organization for Standardization

"… ***digitized code values*** may be referred to as ***picture elements***, or ***pixels***" but
"The term ***resolution*** should not be used …"

ISO 12231 (published 2005-02-01)

Photography -- Electronic still picture imaging -- Vocabulary

2 Terms and definitions

2.1 ***addressable photoelements*** — number of active photoelements on an image sensor. This is equal to the number of active lines of photoelements times the number of active photoelements per line.

NOTE **The term *resolution* should not be used when referring to the number of addressable photoelements** on an image sensor. It is possible that the number of addressable photoelements may be different for the different colour records of an image. When the signal values of the photoelements are digitized, **the digitized code values may be referred to as *picture elements*, or *pixels***.

ixels and Me: a journey of historical