ECE 438 Introduction

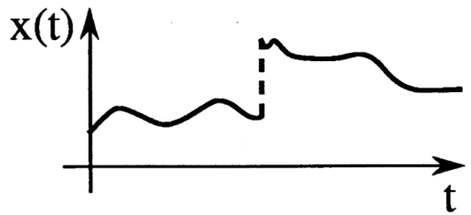
Jan P. Allebach

9 January 2023

What is DSP (1/4)?

- Analog Signals

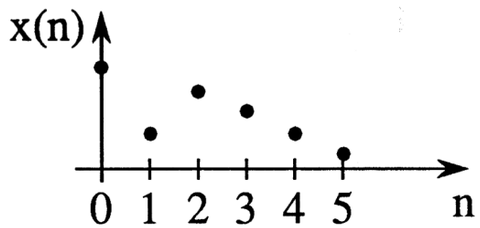
Continuous-time (CT) (analog)



Note that signal need *not* be continuous in amplitude.

- Discrete-Time Signals

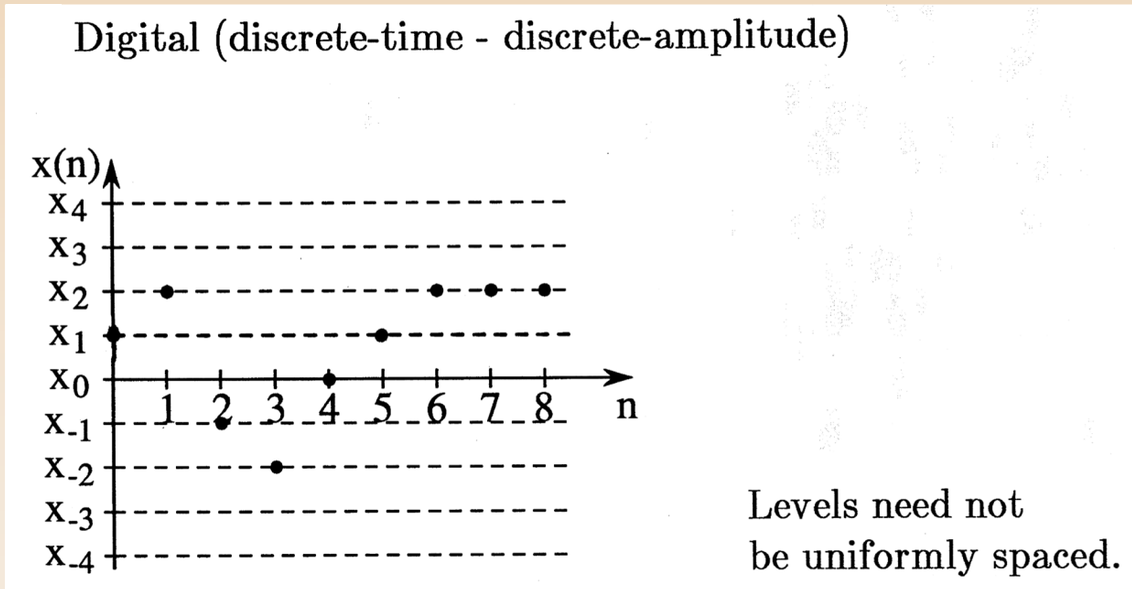
Discrete-time (DT)



Signal is undefined between sampling instances.

What is DSP (2/4)?

- Digital Signals



What is DSP (3/4)?

1. In practice, we work with digital signals; but in most of the theory, we make no distinction between discrete-time and digital signals.

2. The independent variable need not be time.

3. x(n) may or may not be sampled from an analog waveform, *i.e.*

$$x_d(n) = x_a(nT) \quad T - \text{sampling interval}$$

digital analog

We will use the subscripts "d" and "a" only when necessary for clarity.

What is DSP (4/4)?

- Application Scenarios
  - Process an input signal to generate an output signal
  - Process an input signal to make a decision

What are the applications of DSP?

Why is DSP important?

- Advantage of processing binary signals
  - Reproducibility
  - Bistable devices
- Analog signal processing vs. digital signal processing
  - Analog components are generally more bulky and expensive
  - DSP is inherently more flexible and more reconfigurable
    - » Discrete mathematical operations vs. analog circuit design
  - DSP has piggy-backed on the evolution of computer technology
    - » Moore's Law
    - » Internet

Jack Kilby

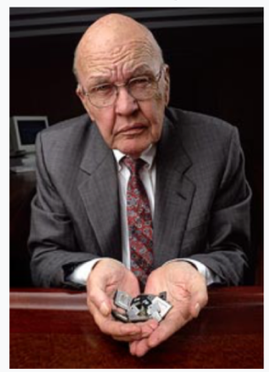
From Wikipedia, the free encyclopedia

Not to be confused with Jack Kirby.

Jack St. Clair Kilby (November 8, 1923 – June 20, 2005) was an American electrical engineer who took part (along with Robert Noyce) in the realization of the first integrated circuit while working at Texas Instruments (TI) in 1958. He was awarded the Nobel Prize in Physics on December 10, 2000.[1] To congratulate him, American President Bill Clinton wrote, "You can take pride in the knowledge that your work will help to improve lives for generations to come."[2]

Kilby is also the co-inventor of the handheld calculator and the thermal printer, for which he has the patents. He also has patents for seven other inventions.[3]

Jack Kilby



Born	November 8, 1923 Jefferson City, Missouri, U.S.
Died	June 20, 2005 (aged 81) Dallas, Texas, U.S.
Nationality	United States

OK, but is this stuff really useful? (1/3)

I was a student of yours (gasp!) almost 20 years ago now… Very fond memories of EE 438 and my time at Purdue.

I'm now working at a military contractor in Cincinnati. **I stayed in Digital Communications – working on Spacecraft Communications links now. We've built the docking link for vehicles visiting the Int'l Space Station, as well as a variety of datalinks for Mars and Low Earth Orbit satellites. Very thankful for the places that my Purdue degree has allowed me to go!**

We have a job opening in Image Processing, for our Infrared Camera Product line - and I was wondering if you know of any current/former students who might be interested?

Ken Fischer, 6 December 2017

Currently Director, Business Development North America, Thales Alenia Space, Newport, KY

OK, but is this stuff really useful? (2/3)

I want to update you with my recent status at Facebook. It's been 1.5 year since I graduated from Purdue and joined Facebook. Last August I was promoted to Senior Research Scientist (E5) and I'm now tech leading a small team. At Facebook I spent most of my time working on building large-scale ads recommendation algorithm using engagement activities on various types of media on Facebook. **On a daily basis we extract high-dimension signals from millions of ad images and videos on Facebook and encode them in deep learner which then predicts probabilities of the users engaging with the candidate ads.** Recently we launched a product Value Optimization which helps eCommerce advertisers find users on Facebook who would like to spend more money on their products. It is now generating millions of dollars for Facebook every day.

With that said, I found the problems I'm dealing with day-to-day are not so much different from my graduate work and I still find the methodology and problem-solving skills learned at Purdue very useful. Therefore I don't want to limit my vision to only the problem I'm solving at work. I want to keep close connection with the application driven studies in academia like problems we solved at EISL.

Yucheng Liu, 5 January 2018

OK, but is this stuff really useful? (3/3)

This is your student Zhulin Peng from your ECE438 class back in 2012/Fall. We also met once at a dinner when you brought your students to the bay area for a conference in 2020.

You were the best professor in the world in my eyes. And I really loved your class when I was back in college. =D

Zhulin Peng, 24 December 2022

Currently Software Test Project Manager, ASML, San Jose, CA

ECE 438 Course Logistics

- Course website
- Course information document
- Course syllabus

ECE 438 Staff

- Antesh Antesh – 1/2-time TA (Tu 08:30a and Th 11:30a lab sections)
- Adnan Hossain – 1/2- time TA (Tu 11:30a lab section and classroom proctor)
- Yang Yan – 1/4-time grader

Antesh Antesh

Adnan Hossain

Yang Yan

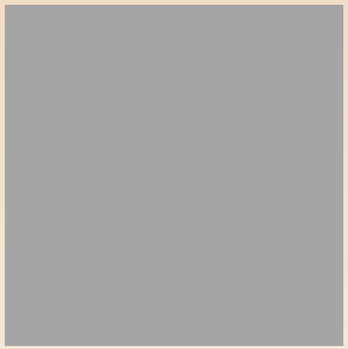
More ECE 438 Course Logistics

- Weekly schedule
- Laboratory information

Applications of Fourier analysis to halftoning*

Halftoning: The process of rendering a continuous tone image with limited number of output levels

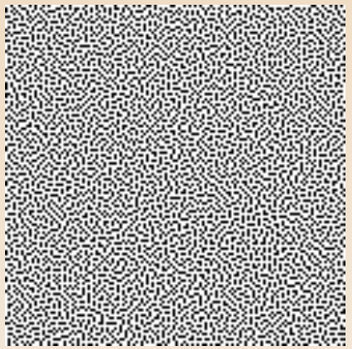
Continuous-tone image

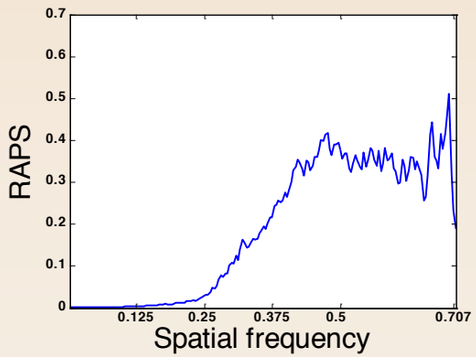


* Madhur Gupta, Data Analytics Lead, Samsung R&D Institute, Delhi

Three important types of halftones

Dispersed-dot

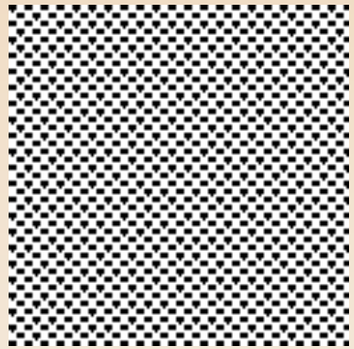


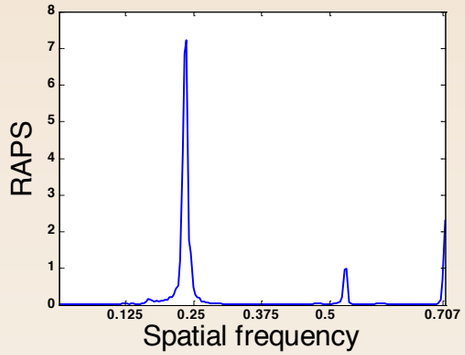


Good detail rendition

Less stable

Periodic clustered-dot



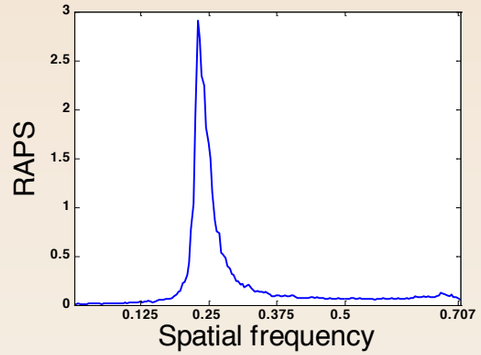


Smooth appearance

Stable (Fewer printer-induced artifacts)

Visible periodic moiré

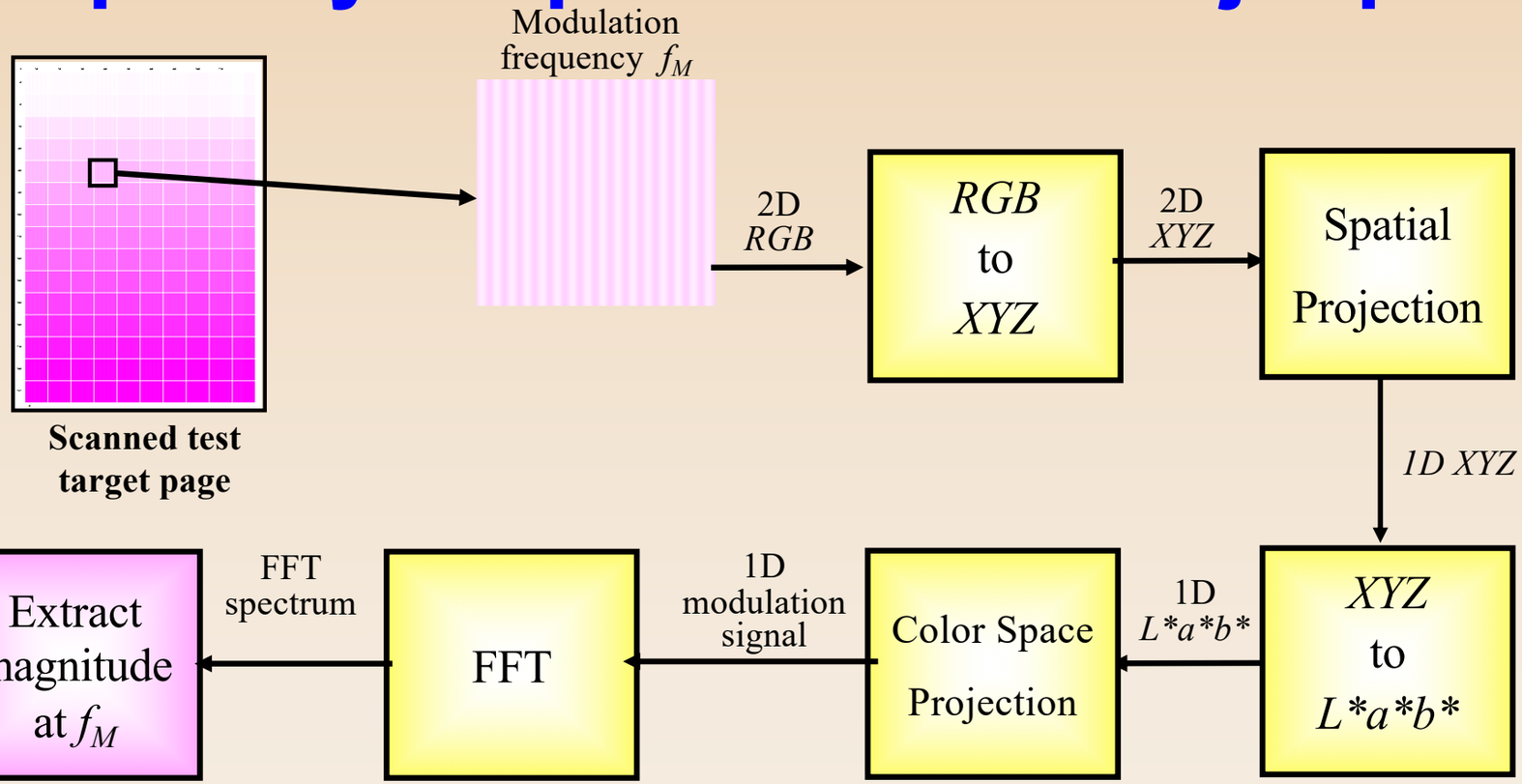
Stochastic clustered-dot



Stable (Fewer printer-induced artifacts)

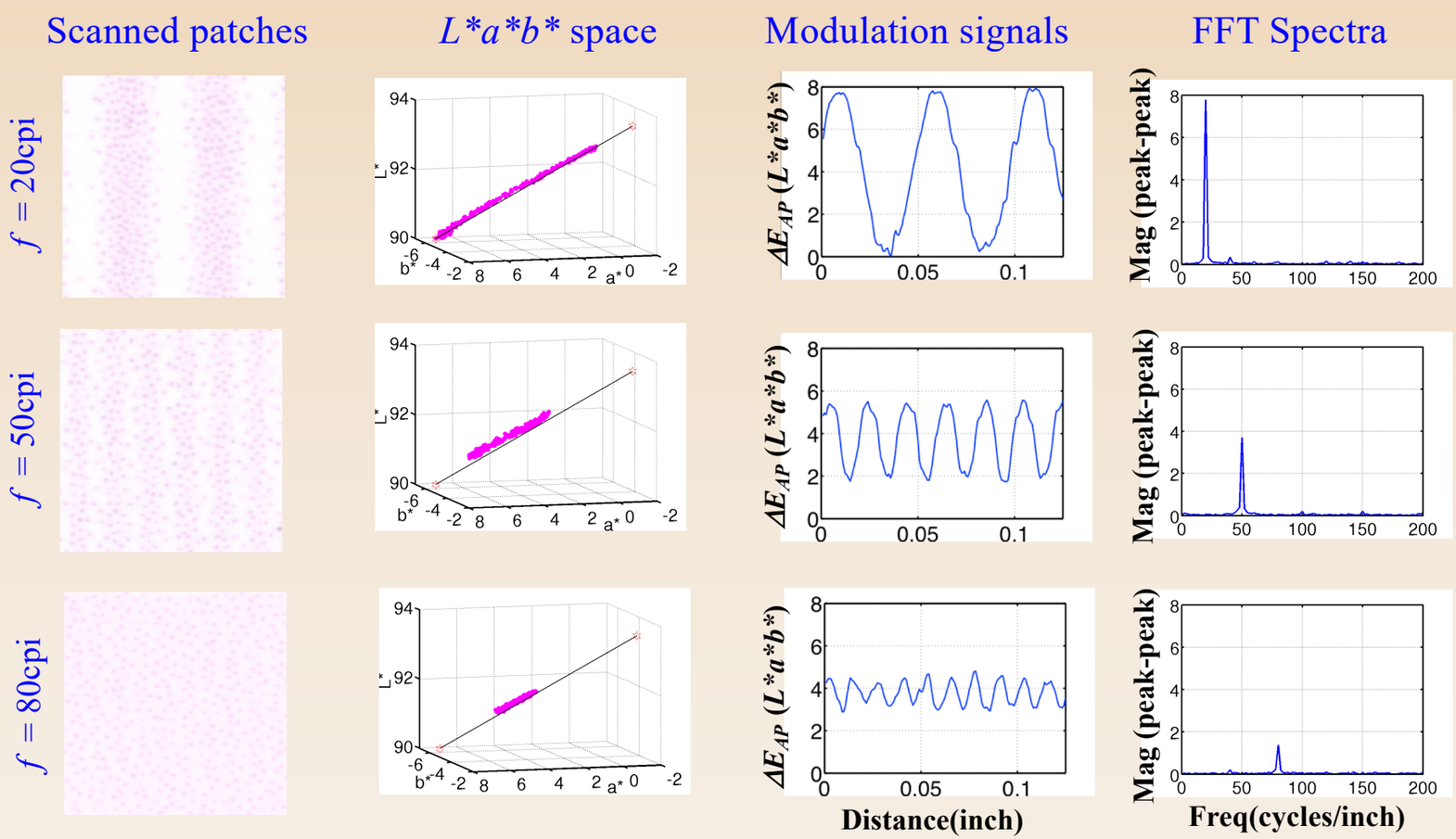
No periodic moiré

Frequency response of an inkjet printer*



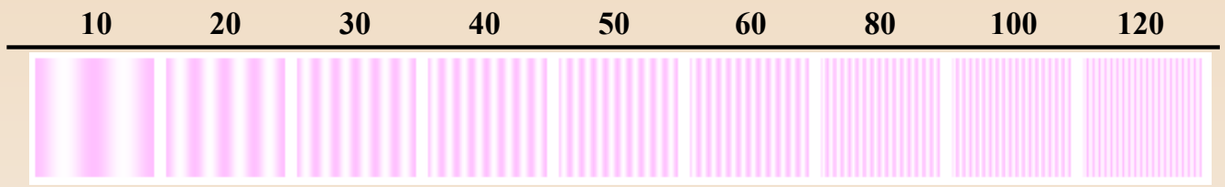
* Young Jang, Principal Engineer, Manager for Camera Systems, Qualcomm, San Diego, CA

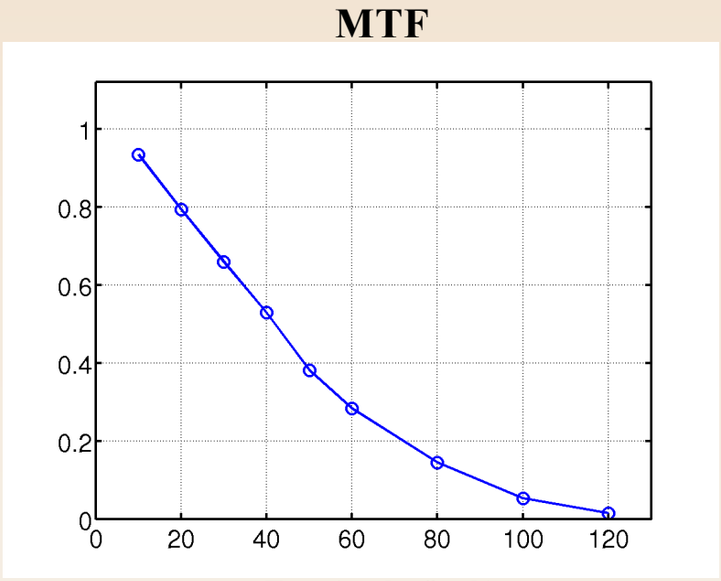
Sample Data at Three Frequencies



Resulting Modulation Transfer Function (MTF) measurement

- 1st row of the WM page.





Solution No. 1 – Arrange dots along edges

Currently Software Engineer, Waymo, San Mateo, CA

- Suggested by Victoria Savikhin

US006760126B1

(12) **United States Patent**
Kritayakirana et al.

(10) **Patent No.: US 6,760,126 B1**
(45) **Date of Patent: Jul. 6, 2004**

(54) **ADAPTIVE HALFTONING METHOD AND APPARATUS**

(75) Inventors: **Kong Kritayakirana**, Sunnyvale, CA (US); **Daniel R. Tretter**, Palo Alto, CA (US); **Qian Lin**, Santa Clara, CA (US)

(73) Assignee: **Hewlett-Packard Development Company, L.P.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 954 days.

(21) Appl. No.: **09/597,862**

ICIP98 Proceedings, IEEE Comput Soc (1998) vol. 3 of 3, pp. 785–789.*

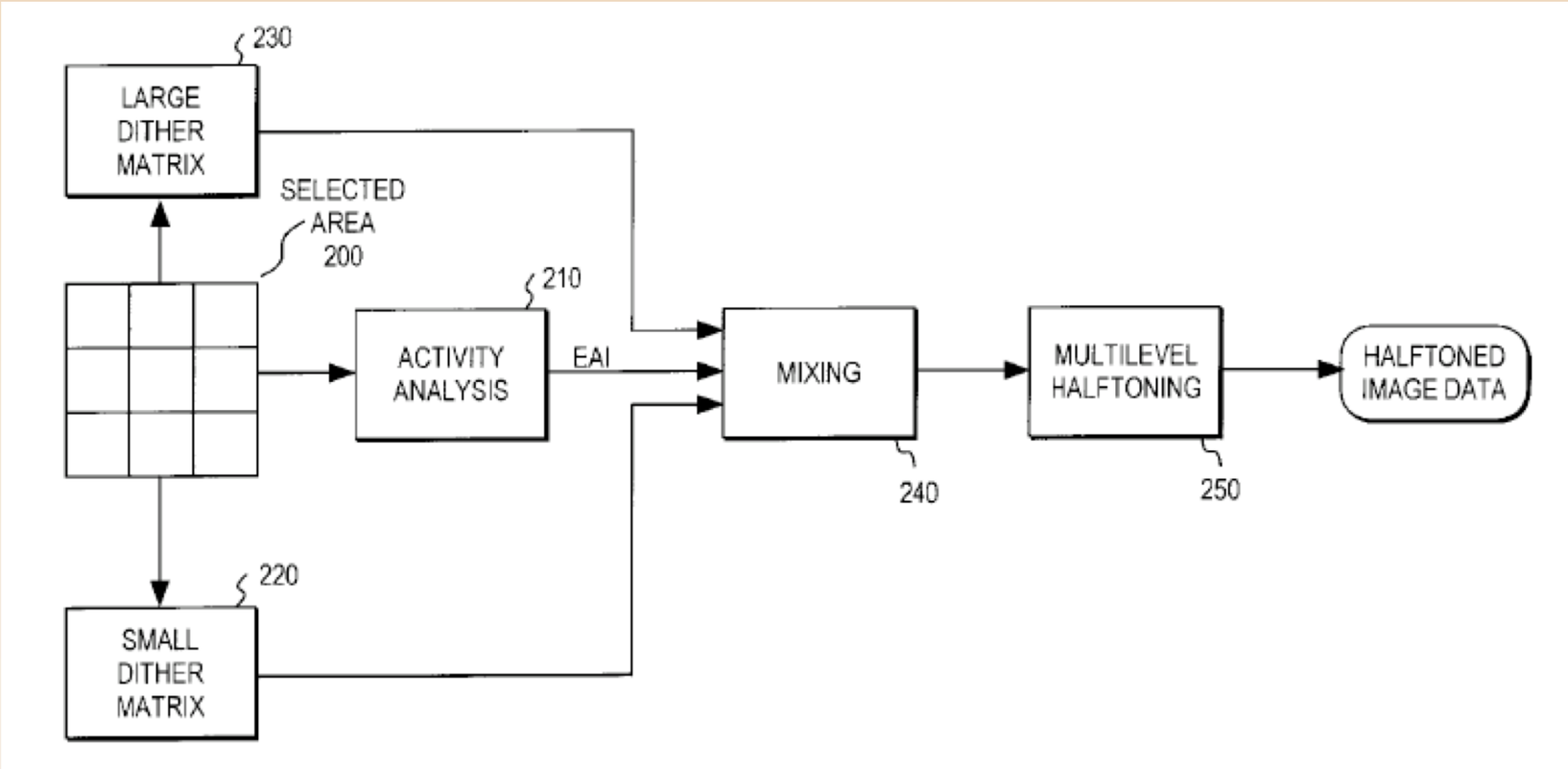
* cited by examiner

Primary Examiner—Scott Rogers

(57) **ABSTRACT**

Methods and apparatus for adaptive halftoning for accommodating a mix of high and low visual activity are provided. Accommodations for white gap reduction and variable darkening are provided for print engine imperfections. A method includes the steps of thresholding a selected pixel of a source image to generate a first dithered output signal, L. The selected pixel is also thresholded to generate a second

Adaptive halftoning – block diagram



Solution No. 2 – pre-emphasize high frequencies to correct MTF

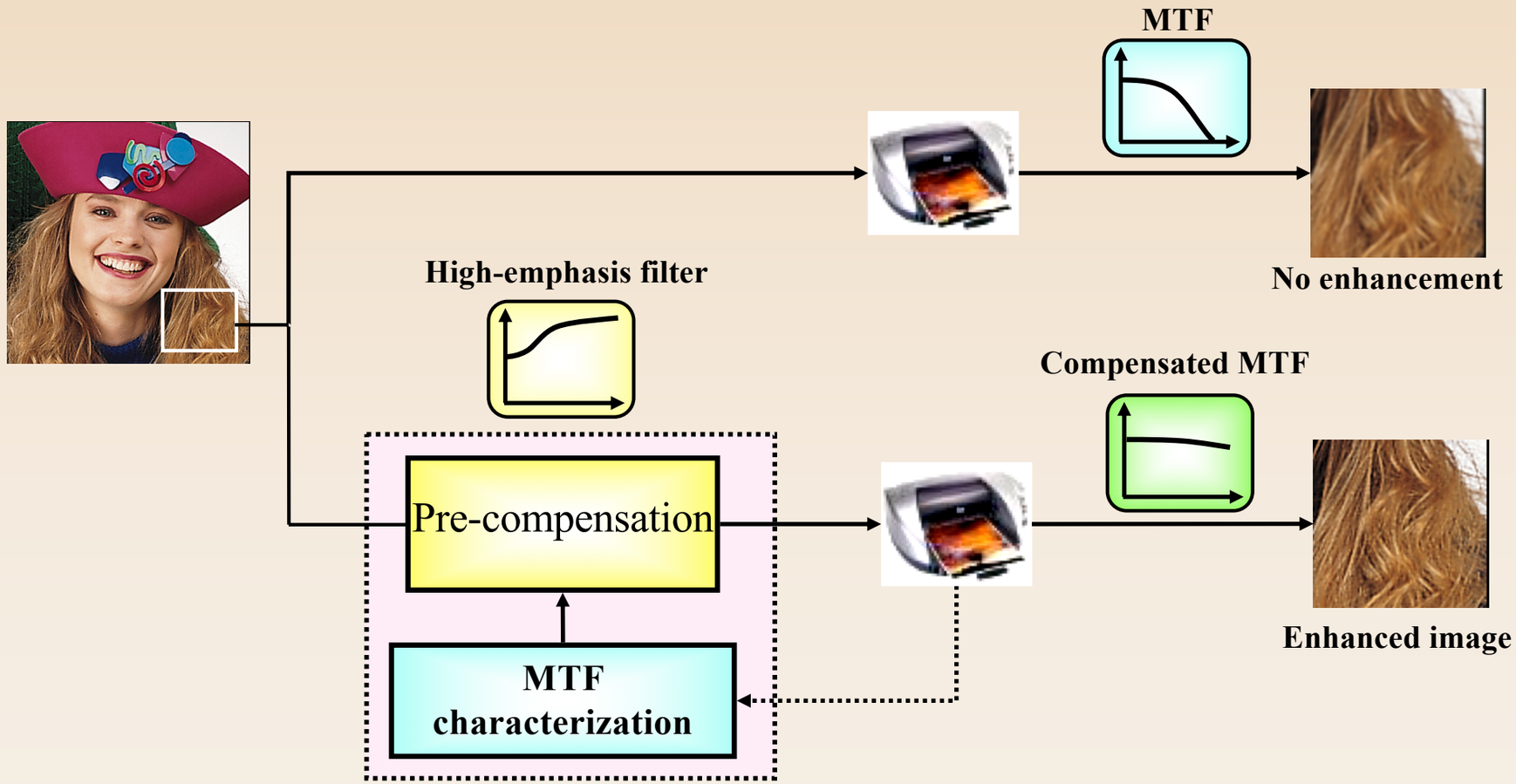


Image sharpening example – original full image

Image sharpening example – cropped portion of image

Original

Sharpened