4 myths about Kees Schouhamer-Immink
IEEE medal of honor 2017
A life in circles
The red thread

• What is a constrained sequence?

• The famous EFM code designed by Immink
Scientific (PhD) Genealogy of Kees Schouhamer Immink (coincidence? http://genealogy.math.ndsu.nodak.edu/)

Ernst Guillemin (München, MIT)
The Mathematics of Circuit Analysis.

Robert Fano

Thomas Kailath (Stanford)
exceptional development of powerful algorithms in the fields of communications, computing, control and signal processing

Piet Schalkwijk (TUE)

Kees Schouhamer Immink (TU Eindhoven)
For pioneering contributions to video, audio, and data recording technology, including compact disc, DVD, and Blue-ray

Medal of honor: 1961

Medal of honor: 2007

Medal of honor: 2017

Han Vinck, June 16, 2017
History: From mechanical to optical recording to ... music-discs are already very old

1885 Oscar Lochmann, Leipzig

the first disc-playing musical box.

1885 Moscow, Russia

Emil Berliner mit der Urform seines Grammophons (1887)

CD/DVD

digital optical recording, was invented in the late 1960s by James T. Russell.

Sony and Philips (CD) made it a commercial and technical success (1983)

Han Vinck, June 16, 2017
Optical recording by James Russell

He succeeded in inventing the first digital-to-optical recording and playback system.

The earliest patent by Russell, US3501586, was filed in 1966, and granted in 1970.

- Sony and Philips paid royalties from CD player sales to Battelle and to ORC
- Time-Warner and other disc manufacturers payed $30 million for patent infringement in 1996
- the patents properly belonged to Russell's employer, he never got a cent out

Anonymus group leader at Philips Research: we did not know about Russell’s patents??

Han Vinck, June 16, 2017
There are **principle differences** between a vinyl record and a CD.

- Needle with direct contact
- Laser
- analog (continuous)
- digital (discrete)
Why digital (binary) instead of analog?

Easier to implement:
- error correction
- data reduction
- encryption
- synchronization
- formatting
- …

Higher Quality at lower Cost

Medal of honor 1966

Han Vinck, June 16, 2017
What is the writing principle on CD?

- Music is represented by a sequence of bits (0 and 1)

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1 0 0 1 1 1 0 0 0 1 0 0 ...
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- Groups of 8 bits are converted into symbols suited for the medium CD (modulation)
What are the symbol constraints for writing on a CD?

Symbol length has discrete values!

- Not too long
- Not too short

Long “CONSTANT” sequences give synchronization problems „we lose track“

Short symbol duration gives detection problems
Words are written as CD landscapes!
For CD: Pits and lands have minimum length 3

Information is in the transition!

\[ 00000010010010 000 01000001000000 \]

Minimum run length: \( d \)-constraint for good detection
\( d = 2 \) gives length 3 in the landscape

there are 277 words of length 14 with at least two 0’s between two 1’s
(for 8 bits we need only 256 words)
Immink modulates 8 bits (music) into constrained words of length 14

- constraints: at least two 0’s between two 1’s

Example:

8 bits 14 bits

0 1 0 1 1 0 0 1 => 1 0 0 0 0 0 1 0 0 1 0 0 0 0

- words are stored using 3 merging bits (to satisfy the constraint we need only 2!)

Example:

0 0 0 0 0 0 1 0 0 1 0 0 1 0

what was Immink’s idea?

Han Vinck, June 16, 2017
Words are written as CD landscapes!

Fact: the **low frequency spectral properties can be improved** (Running Digital Sum)!
Core idea for the famous EFM (2,10) modulation code for CD (patent)

CONSTRUCTION: there are 277 words of length 14 with at least 2 0’s between 2 1’s
- remove all words with a segment of 11 or more 0’s
- remove all words with 9 or 10 zeros at the beginning or end

Then,

\[ 277 - 20 = 257 \text{ words left, JUST enough to store 8 bits} = 256 \text{ words} \]

Result 1: the combination of words has a maximum of \( k = 10 \) (ten) 0’s between 2 1’s
   for landscape variation

Result 2: the minimum number of zeros is 2!

Han Vinck, June 16, 2017
Actually, there is one more important property (not many people talk about)

Constrained code: 010001001000 0001000010000

8 information bits in 17(16) positions

minimum duration of pit (land) = 3 units!

Traditional coding: pits and lands must have the same minimum duration

8 information bits in 24 positions

minimum duration of pit (land) = 3 units

DENSITY GAIN ≈ 30%

A disadvantage can have advantages (Johan Cruijff)

Han Vinck, June 16, 2017
SONY(Toshi Doi, Ed. Rh.-1981): *Kees, we take your code if you can implement it with less than 100 gates!*

On an Apple !! Immink succeeded to beat Sony!
This is the CD patent for the EFM code

Takanawa Prince Hotel (Shinagawa), close to Sony headquarters

owner is Sony!?
The patent for the DvD, EFM+, has only one inventor

Suppose that you are in a hurry at the airport and they ask you to spell your name (K S-I)!
The CD is very noisy (dust, scratches, etc)

SONY contributed error correcting (Reed-Solomon) codes!

As a result: this situation is "equivalent" to

at a price of 25% efficiency loss
Contribution to Error control of CD!

United States Patent

Odaka et al.

ERROR CORRECTABLE DATA TRANSMISSION METHOD

Inventors: Kentaro Odaka; Yoichiro Sako; Ikuo Iwamoto; Toshitada Doi, all of Kanagawa, Japan; Lodewijk B. Vries, Eindhoven, Netherlands

Assignee: Sony Corporation, Tokyo, Japan

Appl. No.: 320,492

Filed: Nov. 12, 1981

Also owned by Sony!?
concatenated codes:
David Forney, Grand-uncle (brother of opa Tom Kailath)

IEEE medal of honor 2015
We also need to follow the correct tracks (control)!

This requires a sequence with regular changes: here is the k-constraint!

T.Kailath, Control
Scientific Grandfather
The third essential patent in CD

United States Patent

Kramer

[54] REFLECTIVE, OPTICAL RECORD CARRIER
[75] Inventor: Pieter Kramer, Eindhoven, Netherlands
[21] Appl. No.: 858,550
[22] Filed: Apr. 23, 1988

Patent No. 5,068,846
Patented: November 26, 1991

On petition requesting issuance of a certificate for correction of inventorship pursuant to 35 U.S.C. 256, it has been found that the above identified patent, through error and without deceptive intent, improperly sets forth the inventorship. Accordingly, it is hereby certified that the correct inventorship of this patent is:

Pieter Kramer,
Gijsbertus Bouwhuis

Piet Kramer: and Bouwhuis in 1991!
4 myths about Kees Immink: #2

- Kees was a professor in South Africa
- no!
- but ...

Capetown, 1993

Dr h.c. at UJ

teaching with a German colleague

Han Vinck, June 16, 2017
4 myths about Kees Immink: #3

• Kees became rich of his work on CD at Philips
  • no!

Suppose she/he gets only 0.001 Euro per CD. Is that too much? (Philips got 10cts)

How many CDs are sold?

By 2007, 200 billion CDs have been sold worldwide

Unfortunately, the dutch patent law is not friendly for inventors, But ...

if the invention is made by an employee of a university or research institution, the employer is entitled to the patent, (Art. 12 (1) Rijksoctrooiwet 1995).

Han Vinck, June 16, 2017
4 myths about Kees Immink: #4

- Immink likes the army and authority
- Incorrect!

BUT:
- Left the Army with S5! Comment Philips: one fool more or less at Research doesn’t matter
- Kees: at Philips Research(then), you were your own boss, lots of freedom
- left Philips at age 51: not enough scientific freedom necessary to function and being creative
What to do after retirement at Philips?

Use IEEE medal of honor:
CONGRATULATIONS to BOTH of YOU!

Han Vinck, June 16, 2017
My favorite digital recording machine

Constrained writing (programming)!
Time for a demonstration!

http://www.youtube.com/watch?v=wF69g0-uh08
http://www.youtube.com/watch?v=jRo8AZzTjRg
A proud „grand-father“

Piet Schalkwijk, TUE
Balthasar Van der Pol (Philips Research) IEEE medal of Honor (1935)

• "For his fundamental studies and contributions in the field of circuit theory and electromagnetic wave propagation phenomena.

Het NatLab leek sterk op het AT&T Bell Laboratorium in de Verenigde Staten. Er werd behalve industrieel ook fundamenteel onderzoek gedaan.

Van der Pol heeft belangrijke bijdragen geleverd aan onderzoek naar de voortplanting van radiogolven,
Sporen volgen – follow tracks

United States Patent

Immink et al.

CONTROL LOOP

Inventors: Kornelis A. Immink; Abraham Hoegendoorn, both of Eindhoven, Netherlands

Assignee: U.S. Philips Corporation, New York, N.Y.

Appl. No.: 48,794

ABSTRACT

Het genereren van een spoorvolgingscorrectiesignaal door middel van twee volgbundels.

Afwijkingsnaar links

Afwijkingsnaar rechts

T.Kailath, Control
Even C.F. GAUSS contributed to the CD principles

- die *gaussche Optik*, a mathematical description of laser light propagation

- the first *binary* wired communication link: 1833, Gauss, Wilhelm Weber and Carl August von Steinheil (München)

- description of Gaussian noise

Without Gaussian noise, no Information and Communication Theory
A Morse code is a constrained sequence

A = 10111
B = 111010101
C = 11101011101

Etc.

Only strings of length 3 and 1 are allowed

Between letters we have 000 (3)
Between words we have 0000000 (7)
A language is also a constrained sequence (Zwynge)

Words:

- sh?
- qu always followed by -a or e or i or o

Order of words:

- grammar
An example close to Immink’s modulation code: the binary puzzle

RULES: Not more than two 0’s and two 1’s next to each other

Remark: The puzzle can be solved! But, the puzzle has to be designed!

To do this, we need „binary mathematics“

Kees can do the last column
Remark: there is a solution!
the calculations for the constrained sequences

Ken Cattermole

Principles of Pulse Code Modulation

John Watkinson

AES Convention, New York, 1985
Claude Shannon, and Kees Immink
Who is the inventor of the binary mathematics?

Leibniz (1646-1716)

He designed a binary computer, "Machina Arithmetica Dyadicae"
- Mechanical version in 1936 by Konrad Zuse
- Technical Museum München

Explanation of Binary Mathematics, 1703
Explication de l'Arithmetique Binaire, 1703

Han Vinck, June 16, 2017
Scientific (PhD) Genealogy of Kees Schouhamer Immink (coincidence?)

http://genealogy.math.ndsu.nodak.edu/

Friedrich Leibniz (1622, Leipzig, binary computing)

Carl Friedrich Gauß (1799, Göttingen, optics)

Ernst Guillemin (1926 München, circuits)

Kees Schouhamer Immink (1985, TU Eindhoven)

T.Kailath (Stanford, Control)