Viterbi’s Impact on the Exploration of the Solar System
October 25, 1963

1. Starting on 10-7-63
2. Starting on 10-21-63
Proof of Optimality of Orthogonal Codes

First Appearance of

\[ \frac{E_b}{N_0} > \ln 2 \]
IV. A Probabilistic Nonsequential Decoding Algorithm

We now describe a new probabilistic nonsequential decoding algorithm which, as we shall show in the next section, is asymptotically optimum for rates \( R > R_0 = E_0(1) \). The algorithm decodes an \( L \)-branch tree by performing \( L \) repetitions of one basic step. We adopt the convention of denoting each branch of a given path by its data symbol \( a_i \), an element of \( GF(q) \). Also, although \( GF(q) \) is isomorphic to the integers modulo \( q \) only when \( q \) is a prime, for the sake of compact notation, we shall use the integer \( r \) to denote the \( r \)th element of the field.

In Step 1 the decoder considers all \( q^K \) paths for the first \( K \) branches (where \( K \) is the branch constraint length of the code) and computes all \( q^K \) likelihood functions \( \prod_{i=1}^{K} p(y_i | a_i) \). The decoder then compares the likelihood function for the \( q \) paths:

\[
(0, a_2, a_3, \cdots a_K), \\
(1, a_2, a_3, \cdots a_K), \\
\cdots \\
(q - 1, a_2, a_3, \cdots a_K)
\]

for each of the \( q^{K-1} \) possible vectors \( (a_2, a_3 \cdots a_K) \). It thus performs \( q^{K-1} \) comparisons each among \( q \) path likelihood functions. Let the path corresponding to the greatest likelihood function in each comparison be denoted the survivor. Only the \( q^{K-1} \) survivors of as many comparisons are preserved for further consideration; the remaining paths are discarded. Among the \( q^{K-1} \) survivors
The performance of the (2,1,6,10) Voyager code

BER vs. Eb/N0 for AWGN and BSC channels.
Jet Propulsion Laboratory
Interplanetary Error-Control Codes

- No Coding (Pre 1969)
- (32,6) Biorthogonal Block Code (1969 - 1975)
  - Plus Reed-Solomon if Data Compression is Used
- Turbo Codes (2004 – ?)
- LDPC Codes (2006 – ?)
No Coding: The Early Mariners

Mariner 2, 1962
- Venus Flyby

Mariner 4, 1965
- Mars Flyby
  - First close-up photographs of another planet.

Mariner 5, 1967
- Venus Flyby
(32,6) Biorthogonal Code + "Green Machine" Decoding

Mariners 6, 7 (1969)
- Mars Flyby

Mariner 9 (1971)
- Mars Orbit

The (8,4) biorthogonal code
<table>
<thead>
<tr>
<th>Project</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mariner 10</td>
<td>1973-1974</td>
</tr>
<tr>
<td>Mercury and Venus</td>
<td></td>
</tr>
<tr>
<td>Viking Mars Landers</td>
<td>1976</td>
</tr>
<tr>
<td>Mars’ Surface</td>
<td></td>
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</tbody>
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The (8,4) biorthogonal code
K = 7, R = 1/2 Convolutional Code with Viterbi Decoding

- Voyagers 1&2 (1977–)
- “Grand Tour”
- Mars Global Surveyor (1997–)

A Sea of Troubles

Mars Pathfinder (1996- 1997)

Sojourner

K = 15 Convolutional Codes with Big Decoding
K = 15 Convolutional Codes with Big Decoding

Cassini (1997 – )

Huygens Titan Probe, 2005


Spirit and Opportunity

Mars Reconnaissance Orbiter (Aug 2005 Launch)

Both use \((8920, 1/6)\) CCSDS turbo code
Back to the Future: LDPC Codes

Mars Telecomm Orbiter 2010

And Beyond?
“The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point.”

“Frequently the messages have meaning”
A Tour of the Solar System

On the Occasion of Andrew Viterbi’s 70th Birthday.

Ludwig van Beethoven, Moonlight Sonata
Daniel Barenboim, pianist
The Far Side of the Moon
Apollo 16
1972
Mars
Mars Global Surveyor
1997
The Surface of Mars
Mars Pathfinder
1998
The Asteroid Gaspra

Galileo

1991
Jupiter
Voyager 1
1979
Jupiter’s moon Io
Galileo
1996
Io above Jupiter
Cassini
2004
Jupiter’s moon Europa
Galileo
2000
Jupiter’s moon Callisto

Galileo

2001
Saturn’s moon Titan
Cassini
2004
Saturn’s moon Phoebe
Cassini
2005
Uranus
Voyager 2
1986
Pluto and its moon Charon

*Hubble Space Telescope*

1994
We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

-T. S. Eliot
Happy Birthday Andy!