The classical algorithm based on the recursive computation of \( M(n) \) for \( n \geq 2 \) is Strassen's algorithm, which requires \( 7 \text{ MULT} \) [4]. If Strassen's algorithm is incorporated into the above described algorithm, then the multiplicative and additive complexities can be further reduced to \( 1.75n \log_2 n \) and \( 1.75n \log_2 n \) respectively.

The reference to the O(n log^2 n) complexity algorithm described in [1] (let us call it \( A_1 \)) may be employed to compute the three-term recurrence relations in \( 0(n \log n) \) computations, arising in a number of other mathematical and engineering situations.

III. CONCLUSIONS

A new algorithm is described for computing the characteristic polynomial of a tridiagonal matrix. This algorithm is based on the application of divide-and-conquer technique to the evaluation of a three-term recurrence relation. It requires \( 0(n \log^2 n) \) arithmetic operations as compared to the classical algorithm that requires \( 0(n^3) \) arithmetic operations.

REFERENCES


Realization of Multiplierless Coherent Detection Scheme in Digital Domain

CHEOL-HO KANG, HEUNGGYOON RYU, AND CHUNG H. LEE

In this letter, a digital NTSC decoder which adopts the multiplierless coherent detection scheme has been proposed for the feasibility of digital composite/component interface. The proposed scheme which has been realized in real-time shows a good performance.

I. INTRODUCTION

Since the late 1970s, there has been much research in processing the composite video signal in digital domain. The techniques for separating a composite video signal into digital component signals have been found in such applications as predictive coding [1], digital TV system [2], etc. It is well known that the composite color video signal consists of the luminance and chrominance components in the same frequency band. The chrominance is a multiplexed signal which results from the quadrature-amplitude modulation. An experimental digital NTSC decoder was developed for the component-coded VTR system [3]. Recently, video signal processors have been reported for the digital color decoding and encoding [4]. But they all used digital multipliers for color demodulation. In this letter we propose a color detection scheme which detects the color components without using digital multipliers.

II. PRINCIPLES AND SYSTEM

The color signals \( R-Y \) and \( B-Y \) are modulated by the subcarrier of 3.579545 MHz and orthogonal in phase diagram [5], where the color burst leads the \( R-Y \) in phase by 90° and the \( R-Y \) leads the \( B-Y \) by 90°.

In analog representation a chrominance signal is expressed as

\[
C = (R - Y) \cos 2\pi f_c t + (B - Y) \sin 2\pi f_c t
\]

where \( R-Y \) and \( B-Y \) denote the color difference signals. \( R \) and \( B \) denote red and blue components, respectively, and \( f_c \) is the frequency of subcarrier (3.579545 MHz).

To detect color components \( R-Y \) and \( B-Y \) should be multiplied respectively by \( \cos 2\pi f_c t \) and \( \sin 2\pi f_c t \) and filtered by low-pass filters. In digital domain, the same procedure is also required to detect the digital color components. This implies that high-speed digital multipliers will be required which are very expensive and complicated to implement.

From (1), \( \cos 2\pi f_c t \) and \( \sin 2\pi f_c t \) used as synchronous signals, which are phase-locked with the color burst signal, can be sampled.
and replaced by the 4fsc clock signal. For the 4fsc sampling rate, the sampled \cos 2\pi fsc \cdot t \text{ and } \sin 2\pi fsc \cdot t \text{ signals become } \cos (n/2) \text{ and } \sin (n/2) \text{ in digital domain. As the integer } n \text{ increases, three values } 1.0, 0.0, \text{ and } -1.0 \text{ alternate between two sequences.}

We can use these sampled signals as control clock for detecting two color components, \( R-Y \) and \( B-Y \), to avoid the multiplication process. When the control logic \( c(n) \) for the scheme as shown in Fig. 1 is "I", the input chrominance signal from the digital bandpass filter is passed and for the logic "O", the input is stopped. In the other case, the input is passed and complemented for the arithmetic operation. This multiplierless digital color detection scheme can be implemented as shown in Fig. 1.

**Fig. 1.** Proposed digital color detector.

When the control clock is phase-locked with the color burst, \( R-Y \) signal lagged by 90° can be detected and \( B-Y \) signal also detected by one sample delay \( z^{-1} \).

### III. RESULTS

A digital chrominance signal is obtained from the output of the digital bandpass filter (BPF) whose input is an A/D-converted NTSC video signal sampled at 4fs rate. The composite video signal (top) and the band pass filtered chrominance signal (bottom) are shown in Fig. 2(a).

Detected color components \( R-Y \) (top) and \( B-Y \) (bottom) are shown in Fig. 2(b).

**Fig. 2.** (a) Input/Output signals of BPF. (b) Detected color components.

### IV. CONCLUSION

The quadrature-multiplexed color components \( R-Y \) and \( B-Y \) modulated by the subcarrier signal have been easily demodulated by the phase-locked 4fs clock signal without resorting to digital multipliers. We have confirmed that the detection process can be realized in real-time via the hardware implementation.

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**Comments on "A New Approach to Recursive Fourier Transform"**

**MICHAEL UNSER**

The above letter calls for two comments; the first relating to the newness of some of the results and the second relating to the practicality of the proposed algorithms. First of all, the recursive structure of the running Fourier transform has been investigated by a number of authors [1]-[6], none of whom is quoted by Amin. Furthermore, the main idea behind the generalization presented in the third section stems from the properties of a yet more general class of features that can be computed using the same recursive structure. This result is expressed by the following theorem to be found in [6].

**Theorem:** A feature \( g(n), \) being a function of the sample values \( x_n, \ldots, x_{n+N-1}, \) satisfies the first order recursion condition

\[
g(n) = w \cdot g(n-1) + w_0 \cdot G(x_{n+1}) + w_1 \cdot G(x_{n-1})
\]

where \( w, w_0, \text{ and } w_1 \) are complex values and \( G(\cdot) \) is an arbitrary function.

\[
g(n) = \sum_{m=0}^{N-1} w^m \cdot G(x_{n+m}) \quad \text{and} \quad w_0 = w^{N+1}.
\]

Examples of quantities sharing this property are the Fourier coefficient \( F(n, w_0) \), the local mean value, the qth order moment, and the z transform (value \( z = z_0 \) (cf. [6], table 1). In particular, the exponentially weighted Fourier coefficient \( F(n, w, \gamma) \) described by Amin is the z-transform evaluated at \( z = ye^{-\gamma} \).

When discussing the issue of computational complexity, the author does not take into account the fact that the use of a windowing function produces running Fourier coefficients that are bandlimited and that there is no major loss of information when \( F(n, w) \) is sub-sampled at a rate of \( N/2 \), which can result in a substantial saving in the number of operations when using a nonrecursive algorithm.

The author also considers the general form of a weighted running Fourier coefficient and suggests expressing the weighting function as a sum of \( 2M + 1 \) geometric series and treating each term separately. There are two major drawbacks with this approach. First, there is generally no guarantee of the existence of such a decomposition. Second, as stated by the author, this method turns out to be quite impractical for large values of \( M \).

When dealing with an arbitrary weighting function, there is an alternative and generally simpler approach which evaluates a given