Al Azhar University
Faculty of Engineering
Electrical Engineering Department

Image Processing Using Residue Number System

A thesis
submitted to the Electrical Engineering Department
Faculty of Engineering – Al Azhar University
for the degree of

(Doctor of Philosophy)

In

Electrical Engineering

(Electronics and Communications)

By

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M. Sc. in Electrical Engineering, 2008

Under Supervision of

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Faculty of Engineering – Al Azhar University

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Abstract

The main parts of the digital signal processing are the mathematical operations. These operations can be done using many algorithms, such as fixed-point, floating-point, logarithmic, and residue number systems. In fixed-point arithmetic, the data format was usually adopted in the first generation of digital signal processor, the major limitation of fixed-point data formats is their restricted dynamic range and accuracy. When a large dynamic range and high precision are required, a floating-point data format or logarithmic is often adopted. The Residue Number System (RNS) is an integer capable of supporting parallel, carry free and high-speed arithmetic. The system also offers useful properties for error detection, error correction, and fault tolerance in digital systems.

An RNS can be used to represent very large integers as residues of manageable word length and to exploit the independence of these residues to facilitate parallel computations.

This thesis is concerned with Image Processing using RNS. The RNS offers the advantage of using integer based arithmetic operations and a simple hardware realization involving arrays of look-up tables stored in high density Read Only Memories (ROMs). In residue number system scaling is necessary to keep the data within the limited dynamic range. The effects of residue scaling on the performance of image processing are described in this thesis.

In this thesis, realizations of many algorithms for image processing using residue number system have been presented. Realization of Discrete Wavelet Transform (DWT), Inverse Discrete Wavelet Transform (IDWT), edge detection, image denoising and image compression are demonstrated. Different examples for each application are given.

Simulation of DWT and IDWT algorithms using RNS are presented. The use of RNS allows the decomposition of a given dynamic range in slices of smaller range on which the computation can be efficiently implemented in parallel. In addition, the power dissipation is reduced by taking advantage of the speed-up due to the parallelism of the RNS structure. Simulation results demonstrate that the suggested algorithm is efficient and faster than the floating-point double precision method with enhancement ratio of 30% in DWT and 71% in IDWT. This algorithm can be used for further studies in the field of image processing.

Edge detection in the field of image processing is one of the most important areas of interest. It is used in many different applications in image processing, such as diagnosis in medical imaging, topographical recognition and automated inspection of machine assemblies. In this thesis a fast wavelet-based edge- detector scheme for digital images is proposed. This scheme is based on properties of the wavelet transform and advantages of the Residue Number System. Simulation results presented in this thesis demonstrate that the suggested algorithm is faster than floating point DWT method with enhancement ratio increasing with the increase in the image size.

There are several types of image denoising available to achieve higher degree of denoising without any significant loss in the visual quality of the image. In this thesis, a proposed algorithm based on Residue Number System is used. The behavior of the mean filter with different type of images is studied. To analyze the performance of the proposed algorithm, Gaussian and Salt and Pepper noise are used. Image quality is measured objectively, using signal-to-noise ratio or picture quality scale, and subjectively, using perceived image quality. The values of the output Signal to Noise Ratio (SNR) of the proposed algorithm, with small wordlength, are all the same as that given by the floating-point double precision method.

Finally, a fast image compression algorithm using Residue Number System is proposed. The use of the RNS allows the decomposition of a given dynamic range in slices of smaller range on which the computation can be efficiently implemented in parallel. Simulation results show that the suggested algorithm is efficient. The output SNR and Peak Signal to Noise Ratio (PSNR) values of the proposed algorithm, with small wordlength (12 bits), are all the same as that given by the floating point double precision method (64 bits).

Published Papers

1. **M. I. Youssef, M. M. Zahra and U. A. Gad “A Fast Wavelet-Based Edge Detector Using Residue Number System”**

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2. **M. I. Youssef, M. M. Zahra and U. A. Gad “A Proposed Image Denoising Algorithm Using Residue Number System”**

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List of Abbreviations

A/D	Analog to Digital
CD	Compact Disk
CDMA	Code Division Multiple Access
CMOS	Complementary Metal Oxide Semiconductor
CPU	Central Processing Unit
CR	Compression Ratio
CRT	Chinese Reminder Theorem
CWT	Continuous Wavelet Transform
DCT	Discrete Cosine Transform
DSP	Digital Signal Processing
DVD	Digital Video Disk
DWT	Discrete Wavelet Transform
ECL	Emitter Coupled Logic
FBI	Federal Bureau of Investigation
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FT	Fourier Transform
IDWT	Inverse Discrete Wavelet Transform
IEEE	Institute of Electrical and Electronics Engineers
IIR	Infinite Impulse Response
JPEG	Joint Photographic Experts Group
LNS	Logarithmic Number System
LoG	Laplacian of Gaussian
LSB	Least Significant Bit
MOS	Metal Oxide Semiconductor
MRC	Mixed Radix Conversion

MRA	Multi Resolution Analysis
MSB	Most Significant Bit
NaN	Not a Number
OFDM	Orthogonal Frequency-Division Multiplexing
PC	Personal Computer
PDEs	Partial Differential Equations
PR	Perfect Reconstruction
PROM	Programmable Read Only Memory
PSNR	Peak Signal to Noise Ratio
RAM	Random Access Memory
RCA	Radio Corporation of America
RNS	Residue Number System
RoI	Region of Interest
ROM	Read Only Memory
SNR	Signal to Noise Ratio
STFT	Short Time Fourier Transform
TDMA	Time Division Multiple Access
TTL	Transistor Transistor Logic
VLSI	Very Large Scale Integration
WS	Wavelet Series