



**University
of Victoria**

Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

IONANA SEVCENCO

MASc (University of Victoria, 2012)

MSc (University of Bucharest, 2004)

BSc (University of Bucharest, 2002)

**“Multi-Dimensional Digital Signal Integration with Applications in
Image, Video and Light Field Processing”**

Department of Electrical and Computer Engineering

Friday, August 10, 2018

10:00 A.M.

Engineering and Computer Science Building
Room 468

Supervisory Committee:

Dr. Panajotis Agathoklis, Department of Electrical and Computer Engineering, University of Victoria
(Supervisor)

Dr. Wu-Sheng Lu, Department of Electrical and Computer Engineering, UVic (Member)

Dr. Daniela Constantinescu, Department of Mechanical Engineering, UVic (Outside Member)

External Examiner:

Dr. Wei-Ping Zhu, Department of Electrical and Computer Engineering, Concordia University

Chair of Oral Examination:

Dr. Timothy Iles, Department of Pacific and Asian Studies, UVic

Abstract

Multi-dimensional digital signals have become an intertwined part of day to day life, from digital images and videos used to capture and share life experiences, to more powerful scene representations such as light field images, which open the gate to previously challenging tasks, such as post capture refocusing or eliminating visible occlusions from a scene. This dissertation delves into the world of multi-dimensional signal processing and introduces a tool of particular use for gradient based solutions of well-known signal processing problems. Specifically, a technique to reconstruct a signal from a given gradient data set is developed in the case of two dimensional (2-D), three dimensional (3-D) and four dimensional (4-D) digital signals. The reconstruction technique is multiresolution in nature, and begins by using the given gradient to generate a multi-dimensional Haar wavelet decomposition of the signals of interest, and then reconstructs the signal by Haar wavelet synthesis, performed on successive resolution levels.

The challenges in developing this technique are non-trivial and are brought about by the applications at hand. For example, in video content replacement, the gradient data from which a video sequence needs to be reconstructed is a combination of gradient values that belong to different video sequences. In most cases, such operations disrupt the conservative nature of the gradient data set. The effects of the non-conservative nature of the newly generated gradient data set are attenuated by using an iterative Poisson solver at each resolution level during the reconstruction. A second and more important challenge is brought about by the increase in signal dimensionality. In a previous approach, an intermediate extended signal with symmetric region of support is obtained, and the signal of interest is extracted from it. This approach is reasonable in 2-D, but becomes less appealing as the signal dimensionality increases. To avoid generating data that is then discarded, a new approach is proposed, in which signal extension is no longer performed. Instead, different procedures are suggested to generate a non-symmetric Haar wavelet decomposition of the signals of interest. In the case of 2-D and 3-D signals, ways to obtain this decomposition exactly from the given

gradient data and the average value of the signal are proposed. In addition, ways to approximate a subset of decomposition coefficients are introduced and the visual consequences of such approximations are studied in the special case of 2-D digital images. Several ways to approximate the same subset of decomposition coefficients are developed in the special case of 4-D light field images. Experiments run on various 2-D, 3-D and 4-D test signals are included to provide an insight on the performance of the reconstruction technique. The value of the multi-dimensional reconstruction technique is then demonstrated by including it in a number of signal processing applications. First, an efficient algorithm is developed with the purpose of combining information from the gradient of a set of 2-D images with different regions in focus or different exposure times, with the purpose of generating an all-in-focus image or revealing details that were lost due to improper exposure setting. Moving on to 3-D signal processing applications, two video editing problems are studied and gradient based solutions are presented. In the first one, the objective is to seamlessly place content from one video sequence in another, while in the second one, to combine elements from two video sequences and generate a transparency effect. Lastly, a gradient based technique for editing 4-D scene representations (light fields) is presented, as well as a technique to combine information from two light fields with the purpose of generating a light field with more details of the imaged scene. All these applications show that the developed technique is a reliable tool for gradient domain based solutions of signal processing problems.