Efficient Solver

by

Haixiang Liu

A dissertation submitted in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy

(Computer Sciences)

at the

UNIVERSITY OF WISCONSIN–MADISON

2018

Date of final oral examination: 01/01/2100

The dissertation is approved by the following members of the Final Oral Committee:
Jane Doeverything, Professor, Electrical Engineering
John Dosomethings, Associate Professor, Electrical Engineering

Please insert your dedication here.

ACKNOWLEDGMENTS

It is customary for authors of academic books to include in their prefaces statements such as this: "I am indebted to ... for their invaluable help; however, any errors which remain are my sole responsibility." Occasionally an author will go further. Rather than say that if there are any mistakes then he is responsible for them, he will say that there will inevitably be some mistakes and he is responsible for them....

Although the shouldering of all responsibility is usually a social ritual, the admission that errors exist is not — it is often a sincere avowal of belief. But this appears to present a living and everyday example of a situation which philosophers have commonly dismissed as absurd; that it is sometimes rational to hold logically incompatible beliefs.

— David C. Makinson (1965)

Above is the famous "preface paradox," which illustrates how to use the `wbepi` environment for epigraphs at the beginning of chapters. You probably also want to thank the Academy.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Numerical simulation of physical phenomenal has long been of the interests in the area of mechanical engineering, physics, and in recent year computer graphics. The research in the field usually falls into two categories: modeling and solver. Research in modeling intends in finding mathematical equations, sometimes with better accuracy, sometimes are easier to solve, that can be used to describe the physical phenomenal. Research in solvers, on the other hand, is to develop algorithms that are able to solve larger equations faster, for iterative approximate solvers, solve to higher accuracy. This dissertation focus on designing efficient solvers, centering on a novel data structure namely SPGrid, which provides the flexibility of a sparse and adaptive data structure while retains the performance of a uniform grid. Furthermore, it will present the use of modern Same Instruction Multiple Data(SIMD) hardware and heterogenous platforms that exploits their high computation throughputs to saturate memory utility. Finally, the efficiency of those design principles and practices are demonstrated in the Poisson and Linear elasticity solvers.

1 INTRODUCTION

This documents presents a set of techniques and algorithms in solving large scale linear equations that emerged from the simulations of physical phenomenal. Those techniques has enabled large scale simulations that provides not only significantly more visual details but also higher fidelity solutions, and exposes challenges that were previously unrecognized in small scale simulations.

Those techniques are demonstrated in the context of heterogenous poisson equation, 2nd order accurate fluid simulation, and large scale linear elasticity solver for topology optimization.

DISCARD THIS PAGE

COLOPHON

This template uses Gyre Pagella by default. (I used Arno Pro in my dissertation.)

Feel free to give me a shout-out in your colophon or acks if this template is useful for you. Good luck!