ELASTIC WAVE MODELLING IN ANISOTROPIC MEDIA USING THE SPECTRAL-ELEMENT METHOD

by

Catherine Ellen Sinclair

B.Eng (Computer Systems)

Department of Physics
School of Chemistry and Physics
The University of Adelaide
SA 5005, Australia

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Abstract

Forward modelling of seismic waves is an essential tool in the determination of the underlying structure of the Earth using inversion techniques. Despite recent advances in computer power and memory resources, full 3-D elastic wave modelling continues to place a heavy burden on a typical personal computer. 2.5-D modelling reduces the computational burden while maintaining 3-D wavefield characteristics. In this thesis I present 2.5-D frequency-domain equations of motion for elastic wave modelling in anisotropic media. The reduced set of equations for vertical transversely isotropic media and tilted transversely isotropic media are presented separately. Using the spectral-element method, I develop the equations of motion into readily implemented sub-equations by identifying simple 1-D and 2-D patterns.

Some aspects of my computational implementation are unique, in particular the use of a system of dynamically growing binary trees to serve as a system matrix. Using this system, the matrix is automatically stored in compressed row format. I investigate the use of both distributed memory and shared memory supercomputers for 3-D modelling and compare the resource use of various matrix solvers.

In this thesis I adapt recently developed Perfectly Matched Layer formulations to the 2.5-D elastic case, and find them to be adequate in most situations. I investigate the possiblity of instability in the absorbing layers.

Observation of 2.5-D modelling results in the frequency-wavenumber domain uncovers pole-like behaviour at critical wavenumbers within the spectrum. I demonstrate how this behaviour threatens the accuracy of the inverse Fourier transformed frequency-domain solution. However for inhomogeneous media, under certain conditions the only medium that exhibits pole-like behaviour is the medium containing the source. Further study of the phenomenon shows that in homogeneous, transversely isotropic media, the critical wavenumber values are not dependent on the receiver position, but rather can be predicted using the maximum phase velocities of the media.

The recommended strategy for wavenumber sampling is to use dense even spacing of values,

to adequately capture the behaviour close to the critical wavenumbers. A further recommendation it to introduce slight attenuation through the use of complex velocities (or elastic constants) to eliminate any pole-like behaviour at the critical values.

Statement

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Catherine Ellen Sinclair and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Catherine Sinclair
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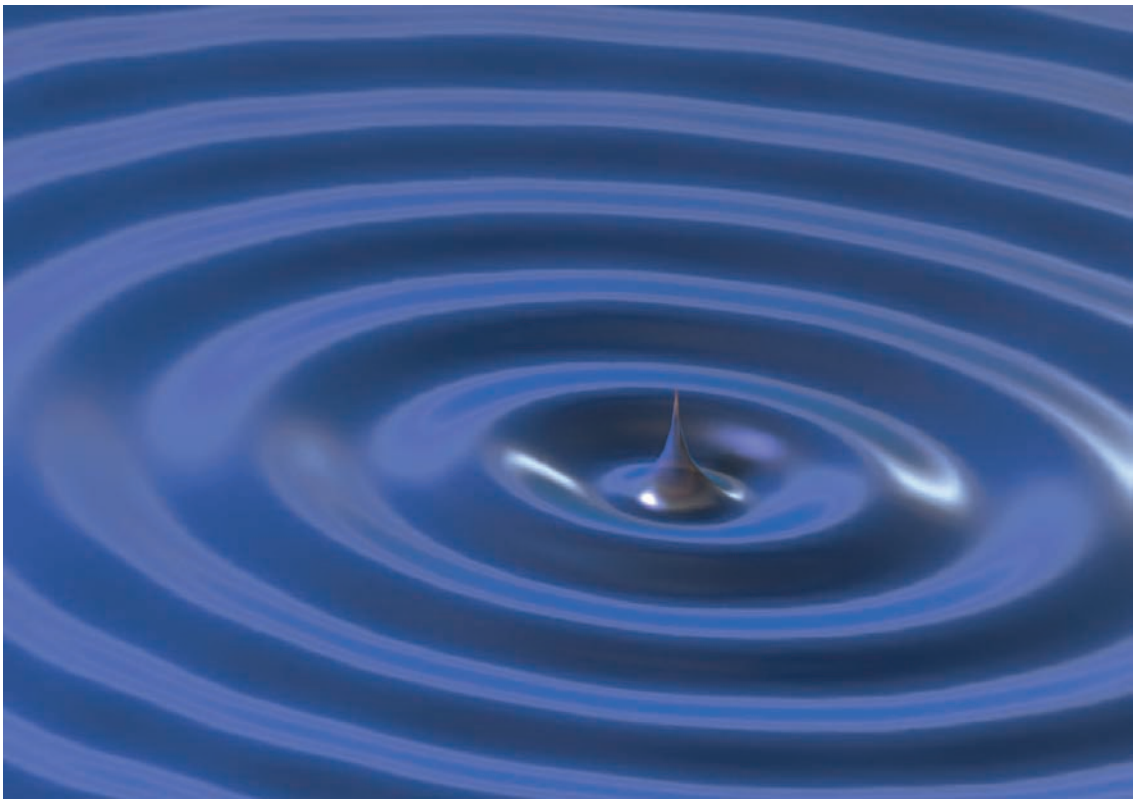

To my husband Bruce.

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