Recent development of the shooting algorithm

Petr Bulant

Department of Geophysics, Charles University, Ke Karlovu 3, 121 16 Praha 2, Czech Republic, E-mail: bulant@seis.karlov.mff.cuni.cz

Abstract

Implementation of the two-point ray tracing algorithm into the Fortran 77 subroutine package CRT, its numerical stability and performance were of the highest priority in the last years. We are far from stating that the problem is solved once for ever. Nevertheless, the progress reached is not negligible.

This brief study is devoted to the numerical tests and comparisons of three different versions of the two-point ray tracing code, demonstrating just the evolution of the code in last three years. The versions are dated to the years 1994, 1996 and 1997. The tests were performed in models L7 and DOM.

Introduction

The three versions of the two-point ray tracing code (Bulant 1996a,b) are dated to November 1994, April 1996 and May 1997. This selection was done in order to demonstrate the progress reached in last three years and in the last year. All the three versions are fully compatible with the package CRT version 5.0 (Bulant, Červený, Klimeš & Pšenčík 1996).

To make the codes comparable, the dimensions of the arrays common to all the three versions were set to the same numbers. The codes have not there own output, (the output is written to the disk via CRT subroutines), and so the writing of the output should not influence computational times of the individual versions. The three versions were compiled with exactly the same compiler options. The computations were carried out on the PC Pentium 90 MHz.

Several quantities were monitored during the computations. These were:

- number of successful computations, i.e. number of computations which finished regularly without any error,
- total computational time including crashed computations,
- computational time per successful computation,
- number of two-point rays identified in each successful computation,
- total number of two-point rays identified.

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1 Computations in model DOM

The first numerical tests were carried out in the DOM model. The model is composed of five layers with constant P-wave velocity or with vertical or combined vertical plus horizontal velocity gradient. The velocity cross section through the middle of the model is displayed in Figure 1. The layers are bounded by plane Earth's surface, plane surface, dipping plane surface, smooth 3-D surface simulating a salt dome and a plane surface faulted by dipping plane. See the Figure 2.

The source-receiver configuration simulates ocean measurements with boat towing the seismic source and two receiver cables, each cable containing 162 receivers. Twenty computations along one linear profile were carried out for the elementary wave reflected at the lowermost faulted interface. Results of computations are displayed in Tab. 1.

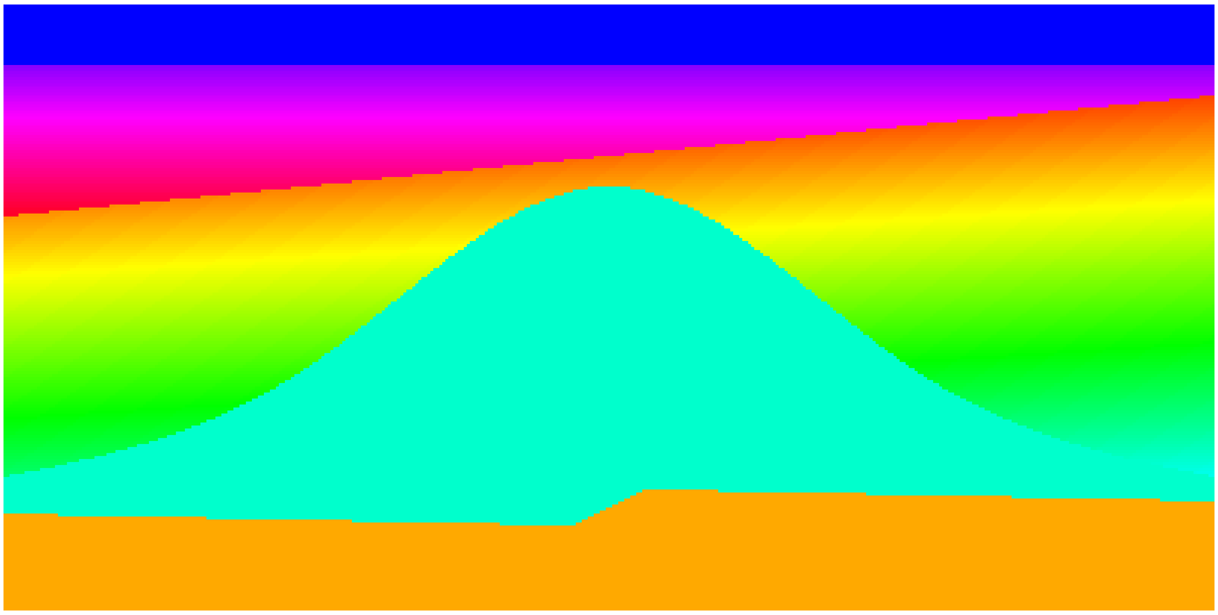

Fig. 1. P-wave velocity vertical section through the DOM model. The velocity is colour-coded ranging from dark blue for the lowest velocity at the top of the model to light blue colour for the highest velocity inside the salt dome layer.

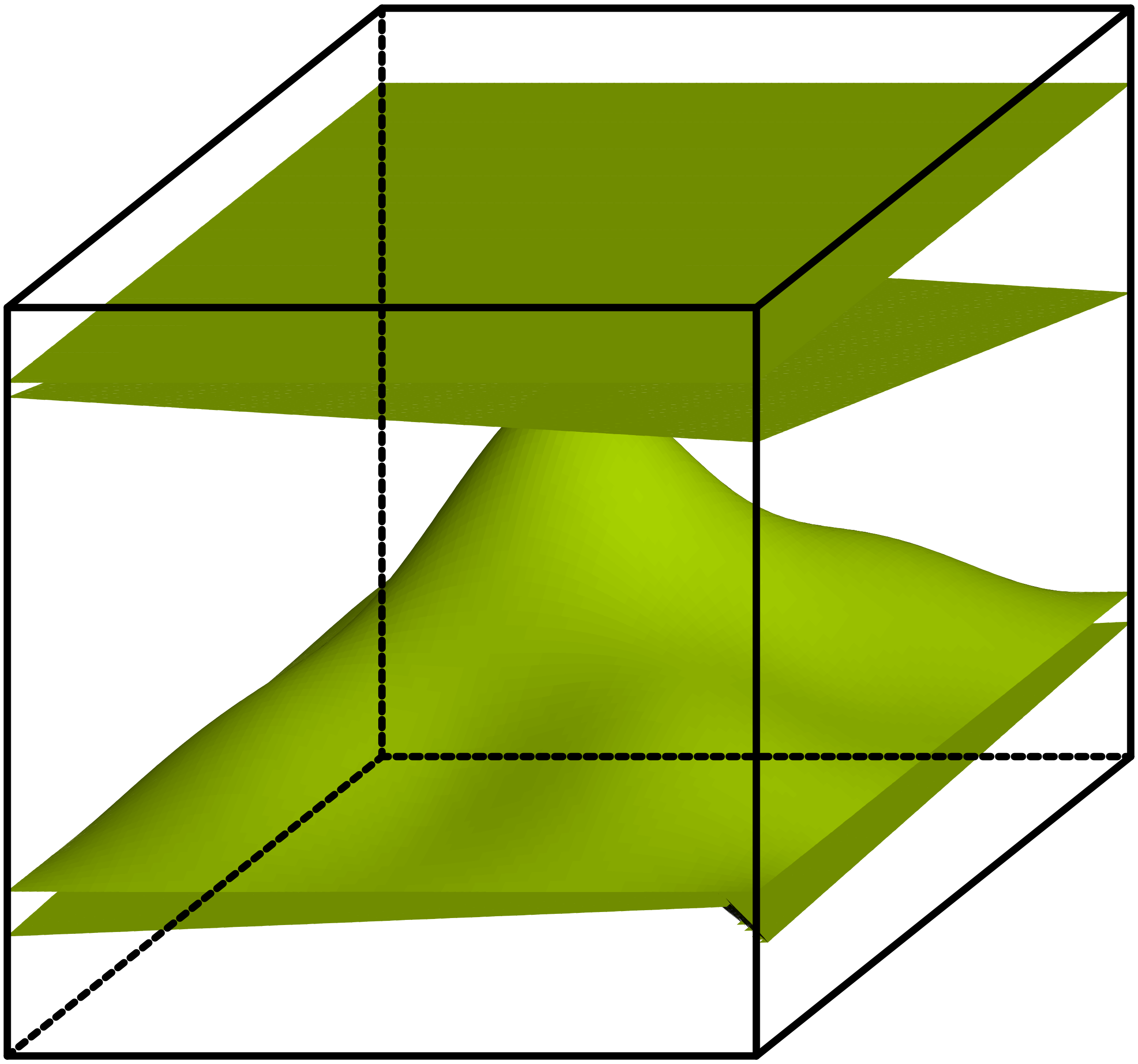

Fig. 2. Structural interfaces in the model DOM.

Version of shooting program		November 1994	April 1996	May 1997
Number of successful computations		0	18	20
Total computational time	(h:min:sec)	1:52:40	0:40:14	0:45:53
Computational time per successful computation	(h:min:sec)	0	0:02:14	0:02:18
Number of two-point rays identified in computation	1	0	15	324
	2	0	0	317
	3	0	3	298
	4	0	0	280
	5	0	0	262
	6	0	0	241
	7	0	0	223
	8	0	67	204
	9	0	80	186
	10	0	106	168
	11	0	148	150
	12	0	123	130
	13	0	104	114
	14	0	86	94
	15	0	69	75
	16	0	52	55
	17	0	24	38
	18	0	0	19
	19	0	0	2
	20	0	0	0
	Total	0	877	3180

Tab. 1. Results of computations in model DOM.

2 Computations in model L7

A three–layer seismic model L7 (Bulant & Klimeš, 1996) is used as the second numerical test to compare the three versions of the two-point ray tracing code. The three layers of the model are bounded by the plane Earth surface and two curved structural interfaces. The uppermost layer has a constant vertical P-wave velocity gradient. The velocity in the middle layer has a vertical gradient higher than the gradient in the uppermost layer, and the velocity in this layer is laterally varying . Lateral variations of the velocity are about twice larger than the vertical gradient. The lowermost layer has a constant (and highest) velocity. The dimensions of the model are approximately 8 x 9.4 x 3 km. The model is based on reflection seismic measurements.

Only the rays corresponding to the elementary wave reflected at the lower interface are taken into account in the computation. The receivers form a linear profile on the plane Earth surface, the point source is situated at the profile. Twenty computations were realized with the source and receivers moving along the profile. The model and the computed two–point rays of shot number 16 are illustrated in Figure 3, corresponding travel-time curve is shown in Figure 4. Results of computations are displayed in Tab. 2.

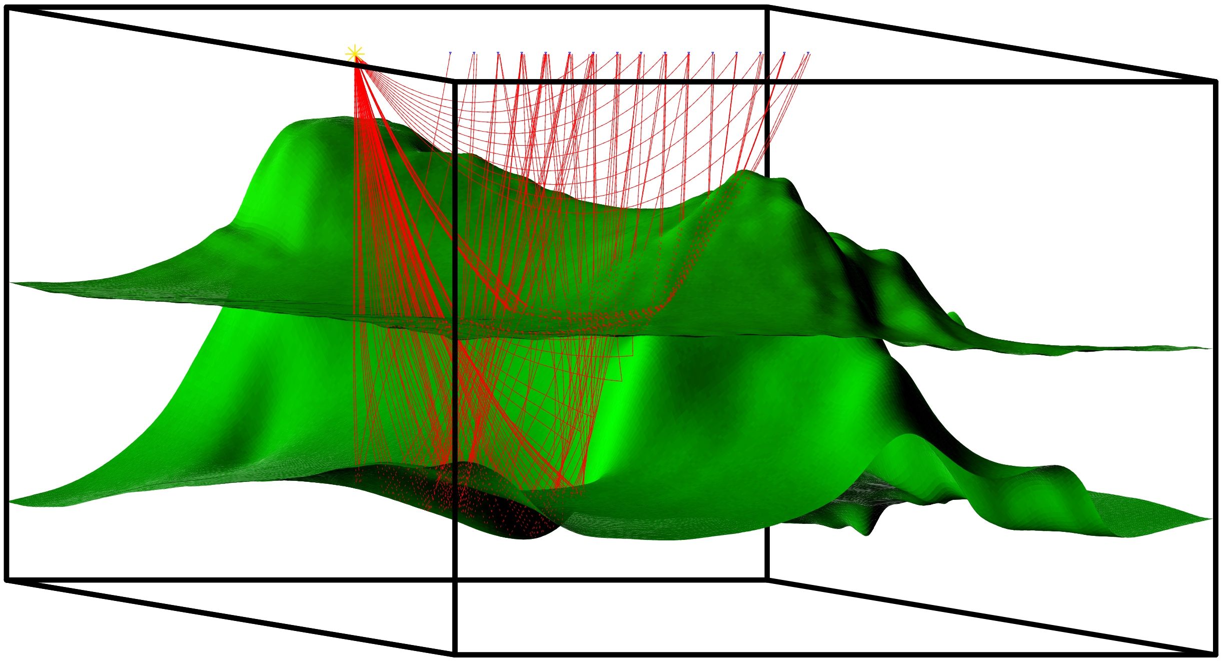

Fig. 3. The three–layer model used for first numerical comparison of the two–point ray tracing codes with the two–point rays identified during the computation for source number 16 and code version 1997. The asterisk represents the point source, the small triangles are the receivers.

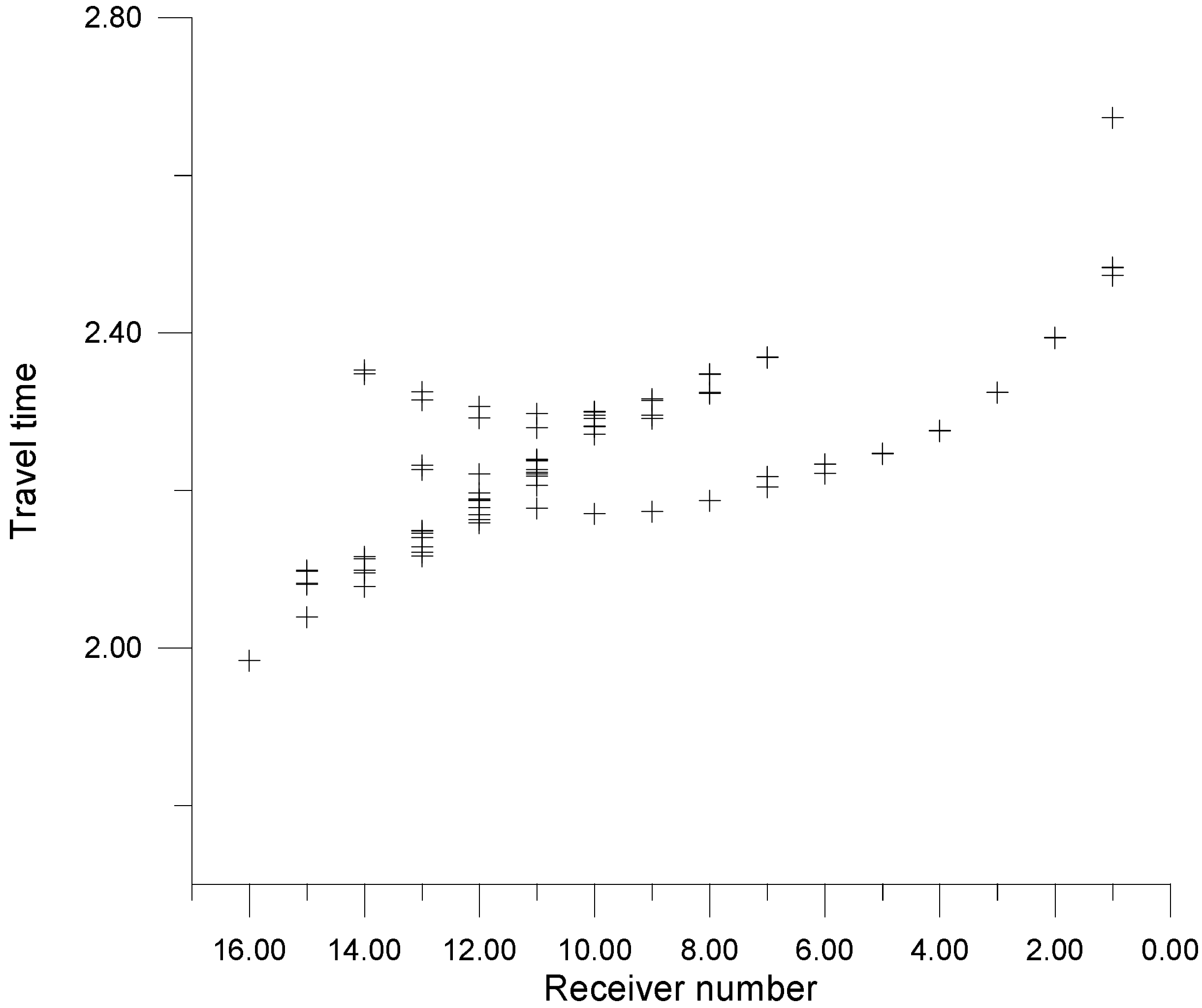

Fig. 4. Travel times of the two-point rays computed in the model L7 during the computation for source number 16 and code version 1997.

Version of shooting program		November 1994	April 1996	May 1997
Number of successful computations		0	0	20
Total computational time	(h:min:sec)	0:03:53	7:25:38	12:01:02
Computational time per successful computation	(h:min:sec)	0	0:02:14	0:02:18
Number of two-point rays identified in computation	1	0	2	13
	2	0	5	12
	3	0	3	13
	4	0	0	13
	5	0	0	15
	6	0	0	17
	7	0	0	17
	8	0	0	22
	9	0	0	26
	10	0	4	31
	11	0	2	32
	12	0	2	44
	13	0	1	48
	14	0	0	60
	15	0	0	82
	16	0	0	86
	17	0	0	57
	18	0	4	52
	19	0	5	46
	20	0	4	46
	Total	0	32	732

Tab. 2. Results of computations in model L7.

Conclusions

As it can be seen from Tables 1 and 2, the numerical stability of the two-point ray tracing code was improved in the last years. The code now appears to be quite stable, at least in presented models. Number of two-point rays, which may be computed, increased dramatically, and the computational costs were decreased.

References

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