Simulation of 3D Acoustic Fields on a Concurrent Computer

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1 Abstract

In this paper. we present a method used to calculate the acoustic field created by a transducer. A parallel computer network was used to elaborate the effectiveness of the direct calculation of the Rayleigh Integral.

2 Introduction

The Rayleigh Integral is given by

$$\Phi(\vec{r}, t) = \iint_S u_n \frac{(r_0, t - r/c)}{2\pi r} dS$$

is a good estimator when the acoustic field is to be derived. Out of the many ways the equation can be solved, emphasis is given to solve the equation directly. For details on how to solve the equation using the impulse response method and angular spectrum method, refer to [3] and [4].

3 Direct Calculation

The transducer and the observation fields are discretized into element points and observational points respectively and the contribution from each transducer element is summed over each observational point [3]. When good approximations are required, both the transducer and the observational field have to be discretized into fine grids. However this would impose heavily on the time consumption of the calculation. To avoid this a parallel algorithm can be applied.

3.1 Parallelization

The set of observation points are chosen for parallel distribution, since:

❑ Each point is independent of the others, which is ideal for parallelization, leading to no communication between spawned tasks [1][2].

❑ When we consider volumetric observations, i.e. 3D simulations, observational point quantity is large, which makes this parallel algorithm more effective.

The spatial coordinates (i.e. x,y,z coordinates) of each observational point is placed in three vectors and are divided according to the number of processors available. Since set of observational points M, cannot be expected to be a multiple of the number of processors P, a general

load balanced linear distribution is assumed [1].With $M=PL+R$ and $0 \le R < P$, we have that:

$$L = \left\lfloor \frac{M}{P} \right\rfloor$$

$$R = M \bmod R$$

Each element m is assigned a processor-index pair as $\mu(m) = (p, i)$ where:

$$p = max\left(\left\lfloor \frac{m}{L+1} \right\rfloor, \left\lfloor \frac{m-R}{L} \right\rfloor \right)$$

$$i = m - pL - min(p, R)$$

This maps $L+1$ components to processes $0 .... R-1$ and L components to the remaining processes.

The communication structures of the master program, which spawns the tasks and the slave programs which carry out the spawned tasks are shown below.

3.2 Master program

```
(1) MASTER PROGRAM
(2) DECLARE
(3)    <declaration of variables from function call
(4)    R,Mp,M,P: integer
(5) INITIALLY
(6)    SPAWN "ppec_slave" to 0,...,P
```
$$(7) \quad M_p = \left\lfloor \frac{M}{p} \right\rfloor, R = M \bmod P$$
```
(8) ASSIGN
```
$$(9) \quad \text{<p:} 0 \le p < P ::$$
$$(10) \quad \text{SEND } x[0, ..., M_p], y[0, ..., M_p], ... \text{ to } p$$
```
(11)    >
```
$$(12) \quad \text{<k:} 0 \le k < P ::$$
$$(13) \quad \text{RECV } resp[0, ..., M_p] \text{ from } k \in P$$
$$(14) \quad \text{TERMINATE } k \in P$$
```
(15)    >
(16) END
```

3.3 Slave Program

```
(1) SLAVE PROGRAM: 0.....p-1//P
(2) DECLARE
(3)    <declaration of variables from Master>
(4) INITIALLY
```
$$(5) \quad \text{RECV } x[0, ..., M_p], y[0, ..., M_p], ... \text{ from MASTER}$$
```
(6) ASSIGN
```
$$(7) \quad \text{<} n \in N = \{elements\} ::$$
$$(8) \quad \text{<i:} 0 \le i < M_p ::$$

```
(9)         resp (i) =+<response from element n>
(10)    >
(11)  >
(12) SEND resp [0, …, Mp ]   to MASTER
(13) TERMINATE
(14) END
```

3.4 Run Time Results

The program was tested for a 64x3 rectangular array transducer and a 101199 observation point volumetric area. The run time results, averaged for 10 runs are in the following table.

nodes	T(n)	T(1)/T(n)
1	152.35	-
2	86.87	1.75
5	35.77	4.26
8	22.74	6.70
10	18.57	8.21
12	15.72	9.69
15	13.16	11.58
18	11.38	13.38
20	10.40	14.65
22	9.73	15.66

4 Software

The acoustic field simulator was implemented on MATLAB based program ULTRASIM, using the MEX mechanism to link C-files. PVM was used to manage the parallel environment.

MATLAB MEX mechanism in itself is a time-saving technique. External C programs specially designed to suit the MATLAB environment reduce the run-time by ca. 3 fold [6]. PVM was chosen over other parallel libraries like MPI due to its capability to call parallel programs directly from the platform. MPI requires a seperate program to call its slaves [1,5].

5 Hardware

To run the parallel program, the IBM cluster at The University Center for Information Technology at the University of Oslo was used. The present configuration of the cluster is:

- ❑ 2 IBM RS 6000/990 machines, with a total of 1.5GB RAM and 20GB of Disc space.

- ❑ 14 IBM RS 6000/590 machines, with a total of 3.5GB RAM and 16GB disc space.
- ❑ 1 IBM SP2 parallel computer with 16 "wide nodes" with 256 MB RAM and 2 GB disc space per node.
- ❑ 1 IBM 7134 disc cabinet with 54GB disc space
- ❑ 1 IBM 9333 disc cabinet with 20GB disc space
- ❑ 1 DEC ALPHA 3000/900 station
- ❑ 1 HP 9000-735/125 station

The simulator was run on the IBM machines only. The parallel network was accessed by SGI workstations and Sun Sparc Stations.

6 Conclusion

The parallel program provides acceptable speed-up when we consider large observational data. The efficiency of this program is even more visible with even larger observational points. It's also worth mentioning that the speed up is only limited by the number of processors available. With a very large number of observation points a better visualization can be achieved, and with more processors, a better speed-up can be achieved.

7 Acknowledgements

8 Reference

1. Eric F. Van De Velde, Concurrent Scientific Computing, Springer-Verlag,1992

2. Ian Foster, Designing and Building Parallel Programs, Addison Wesley, 1994

3. Lars Odegaard , Sverre Holm,"Acoustic Field Simulation for Arbitrarily shaped Transducers in a Stratified Medium", Proc. IEEE Ultrasonics Symposium, November 1994

4. Sverre Holm, "Simulation of Acoustic Fields from Medical Ultrasound Transducers of Arbitrary Shape", Proc. IEEE Nordic Symposium in Physical Acoustics, Ustaoset, Norway, 1995

5. Al Geist, Adam Beguelin, ...,PVM 3 User's Guide and Reference Manual", Oak Ridge National Laboratory,1994

6. Matlab User Guide, External Interface Guide, The Mathworks Inc., 1993