Artificial Bee Colony Algorithm using MPI

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OVERVIEW

Introduction
Components
Working
Artificial Bee Colony algorithm (RAM)
Artificial Bee Colony algorithm (Parallel)
Performance
An Alternative Parallel Approach
Observations / Limitations
Future goals
References

INTRODUCTION

Artificial Bee Colony (ABC) algorithm is a swarm-based meta-heuristic optimization algorithm.

Algorithm based on the foraging behavior of bees in a colony.

Applications :

Optimal multi-level thresholding, MR brain image classification, face pose estimation, 2D protein folding

COMPONENTS

Food Source :

A food source location denotes the possible solution (vector with n parameters) .eg. Amount of food in the source denotes quality (fitness).

Employed Bees :

Retrieve food from source and report back neighboring sources. One bee per source.

Scout Bees :

Find and update different sources. Employed bees whose food source is exhausted become Scout bees.

Onlooker Bees :

Choose food source based on inputs from Employed bees.

WORKING

Initialization phase :

Vector x_m (m = 1 … SN). Each vector x_m contains n variables (1 … n) . $x_{mi}=l_i+rand(0,1)*(u_i-l_i)$. l_i, u_i = *bounds* *--- (1)*

Employed bees phase :

Food source $u_{mi}=x_{mi}+\phi_{mi}(x_{mi}-x_{ki})$ *--- (2)*

Fitness function $fit_m(\vec{x}_m) = 1/(1 + f_m(\vec{x}_m))$ *--- (3)*

Onlooker bees phase :

Probability $p_m = fit_m(\vec{x}_m) \;/ \sum_{m=1 \ldots SN} fit_m(\vec{x}_m)$ *--- (4)*

Scout bees phase :

New food sources are randomly selected and solutions selected based on *(1).*

WORKING

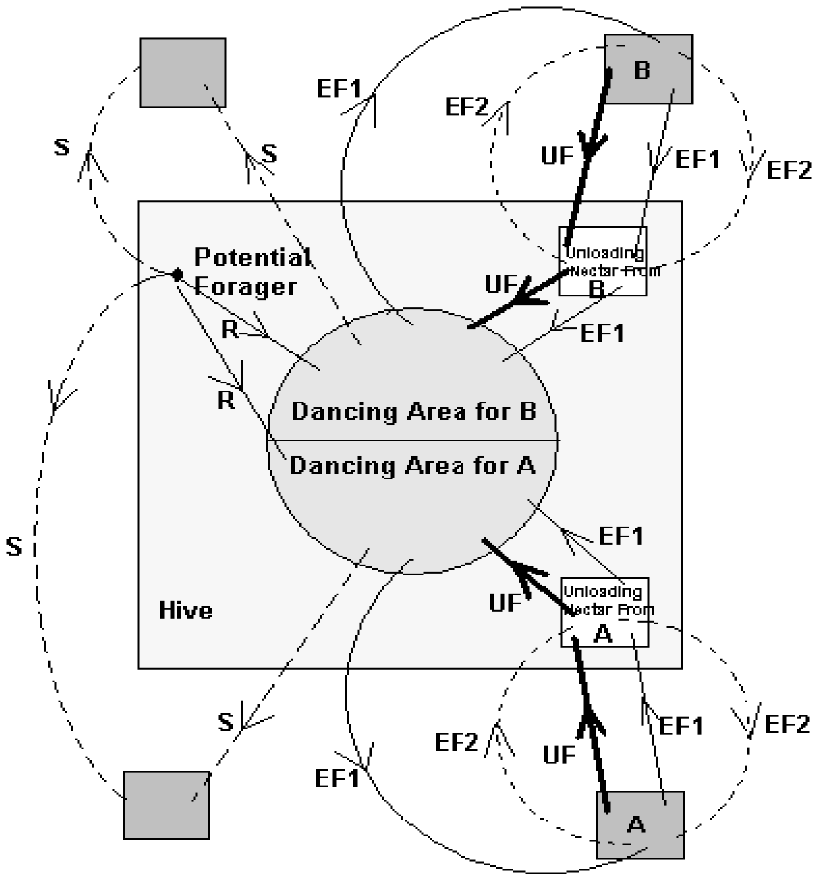

Figure 1. The behaviour of honey bee foraging for nectar

WORKING

Serial representation – n Rows, single processor (n food sources)

1	4.113152	7.630029	18.6177	9.005129	17.91446
2	9.935555	13.37011	4.745863	10.6545	19.78366
3	10.95558	19.49226	17.84674	10.75404	18.06841
4	18.53284	0.792465	18.59932	3.516931	14.82533
5	14.34575	3.136435	5.886008	6.576565	7.916828
6	17.86021	14.02121	17.46455	14.59524	16.75909
7	3.731504	5.224778	16.29288	11.44785	0.314989
8	0.627248	13.82126	3.269592	13.46171	13.24224

WORKING

Parallel representation - n Rows split among m processors (n/m food sources per processor)

1	4.113152	7.630029	18.6177	9.005129	17.91446
2	9.935555	13.37011	4.745863	10.6545	19.78366

3	10.95558	19.49226	17.84674	10.75404	18.06841
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DATA AND PROCESSORS USED

Programming Language : C++ with MPI
# of Processors : 1-16. 8 cores per processor. (Total 128 cores).
Size of data (data type = float):

- 65536 X 5
- 65536 X 40
- 512000 X 10
- 768000 X 10
- 8192 X 20

Upper limit = 10, Lower limit = -10

Criterion for termination of program :

- global_minimum = 0.000001 (OR) max_cycle = 1000

Number of runs for each data set and processor # : 10
Functions used :

- Sphere : $f(x) = \Sigma x_i^2$ $(i = 1 – D)$
- Rastringin : $f(x) = \Sigma (x_i^2 - 10*\cos(2\pi*x_i) +10)$ --- $(i = 1 – D)$

RAM ALGORITHM

- Start
- Initialize parameters
- Initial solution
- REPEAT
  - Find and evaluate solution by Employed bees
  - Select and update food source by Onlooker bees
  - Evaluate solution by Onlooker bees
  - If solution is abandoned, generate new solution by Scout bees
- UNTIL criteria are met
- End

PARALLEL ALGORITHM

- Start
- Initialize parameters
- Divide populations into sub-groups for each processor
- Initial solution
- REPEAT
  - Find and evaluate solution by Employed bees
  - Select and update food source by Onlooker bees
  - Evaluate solution by Onlooker bees
  - If solution is abandoned, generate new solution for Scout bees
  - Exchange information within sub-groups (local worst/best solutions)
- UNTIL criteria are met
- End

PARALLEL ALGORITHM

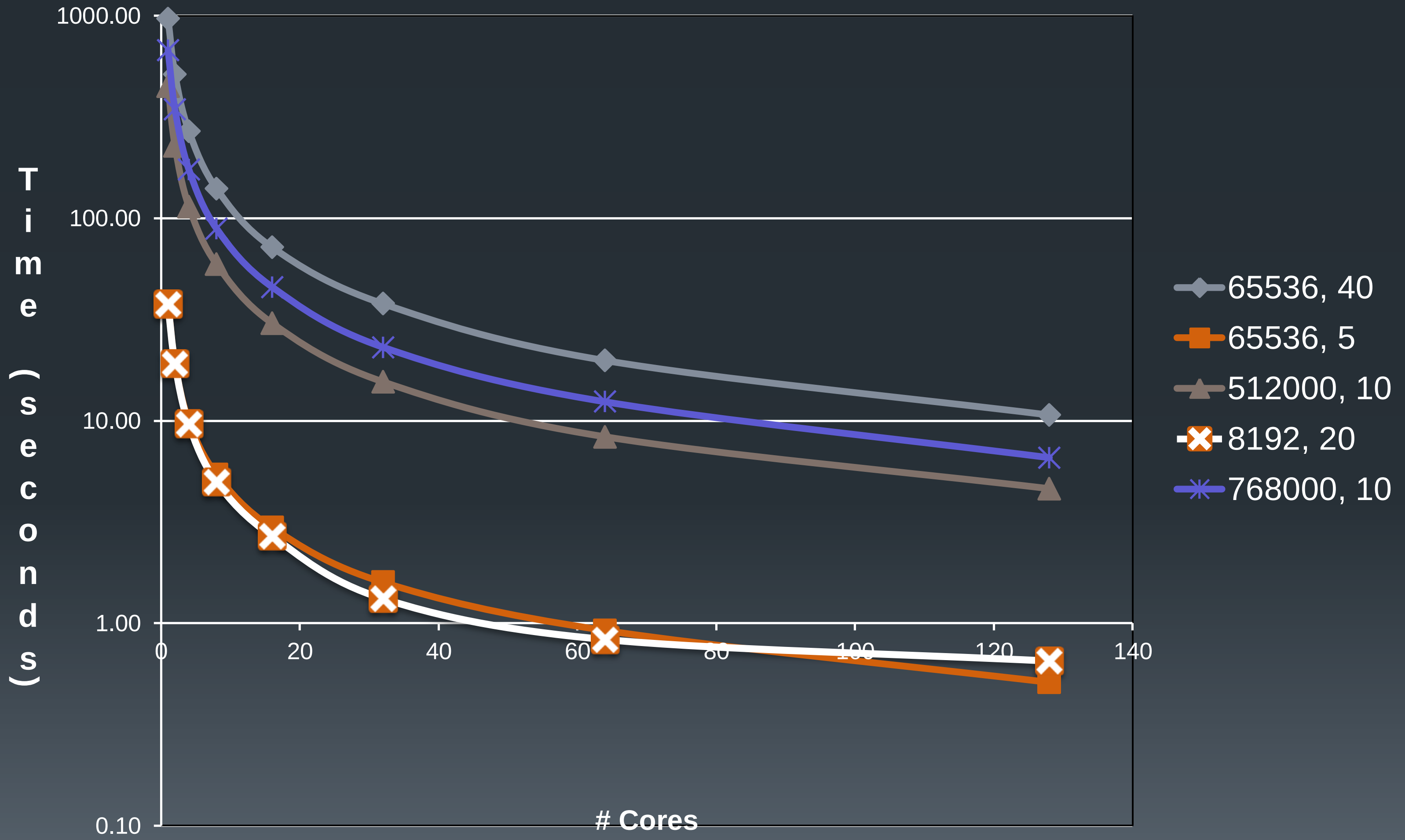
1. For each cycle, Processor 0 generates random pairs and communicates the pairing to the remaining processors (MPI_Send, MPI_Recv)
2. At the end of each cycle, the processors replace the local worst solution with the local best solution obtained from their respective partners.
3. After the desired criteria are met, the processors exchange local best solutions and receive the overall best solution (MPI_Allreduce)

VALUES OBTAINED

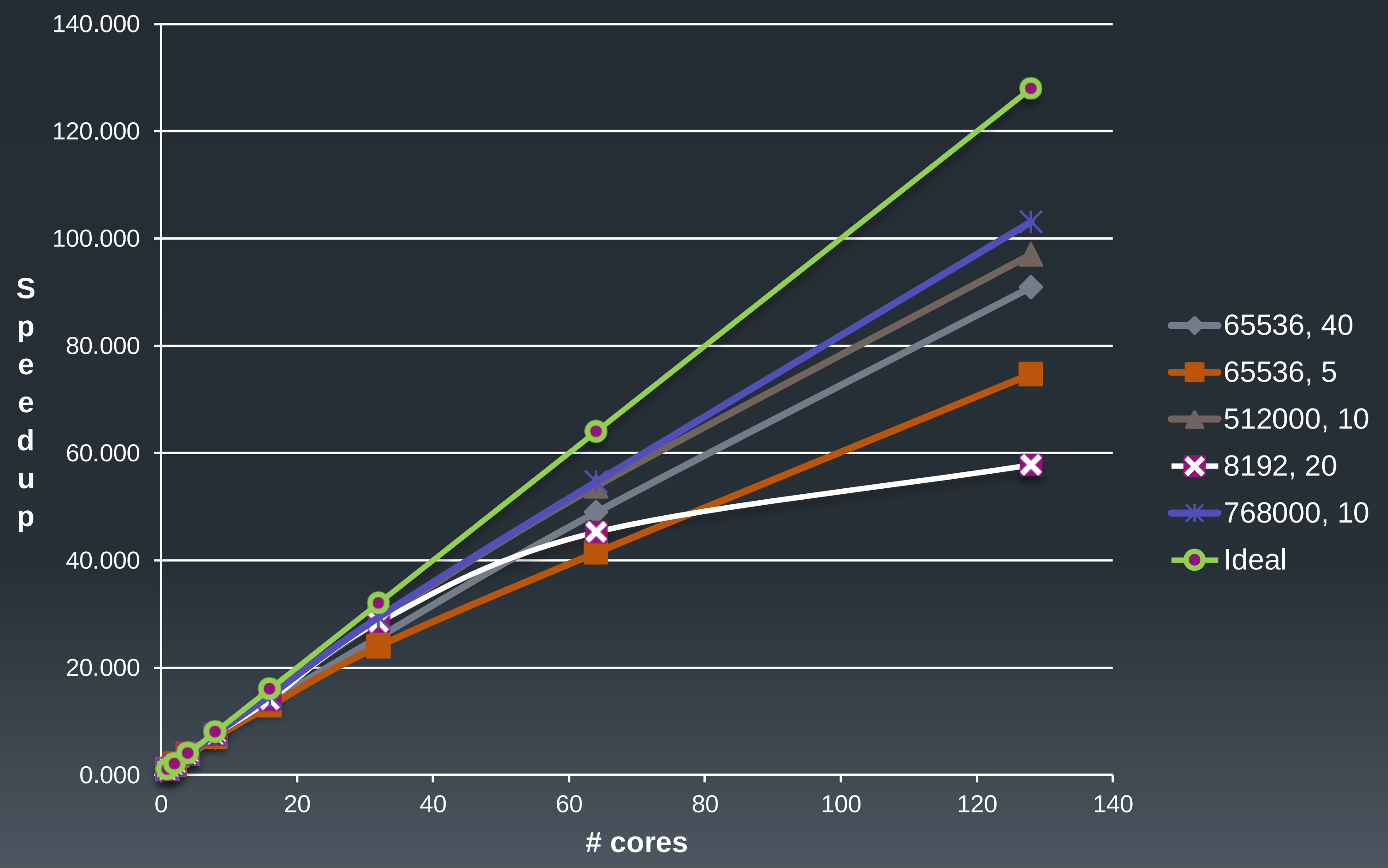
- Time taken for different data sizes and # cores
- Input data = #Food sources, #Parameters per food source

	65536, 40	65536, 5	512000, 10	8192, 20	768000, 10
1	970.23	38.11	448.37	37.56	677.45
2	513.21	19.21	227.46	19.13	344.87
4	269.41	9.94	114.34	9.61	174.15
8	139.84	5.42	59.26	4.98	88.85
16	71.91	2.96	30.32	2.69	45.77
32	37.81	1.59	15.96	1.32	23.06
64	19.83	0.92	8.33	0.83	12.40
128	10.67	0.51	4.62	0.65	6.57

PERFORMANCE – Time vs # cores



PERFORMANCE - speedup



AN ALTERNATIVE PARALLEL APPROACH

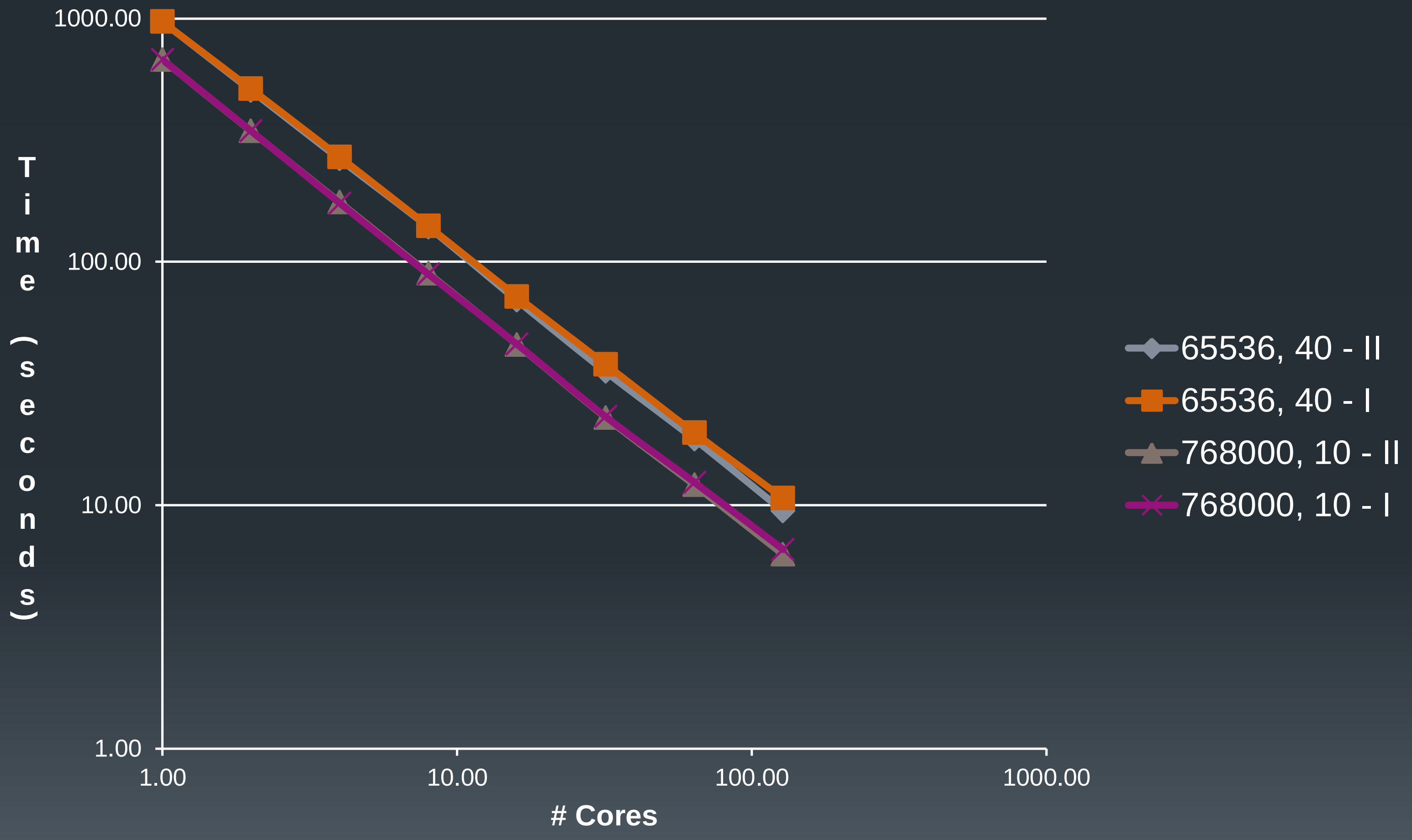
- Best solutions are not exchanged between processors between cycles.
- After criteria are met, Local best solutions are exchanged between processors and the overall best solution is chosen.

VALUES OBTAINED

- Time taken for different data sizes and # cores
- Input data = #Food sources, #Parameters per food source

	65536, 40	65536, 5	512000, 10	8192, 20	768000, 10
1.00	970.23	38.11	448.37	37.56	677.45
2.00	506.11	19.83	230.47	19.04	344.03
4.00	263.85	10.51	116.64	9.89	175.59
8.00	138.73	5.89	61.72	5.06	89.67
16.00	69.34	3.05	20.15	2.67	45.65
32.00	35.29	1.61	15.22	1.45	22.89
64.00	18.64	0.89	8.14	0.92	12.08
128.00	9.45	0.48	4.45	0.63	6.26

PERFORMANCE – Comparison of both approaches



OBSERVATIONS / LIMITATIONS

- Time taken to execute increases based on the number of Food Sources (linear) and number of Parameters per Food Source (non-linear, possibly polynomial).

- For a given number of processors, speedup increases as the number of parameters. (Increase w.r.t. time in inter-process communication is linear while increase within each processor is non-linear).

- For a fixed number of food sources, speedup gradually decreases as the number of processors increase, as seen in the speedup of the data set (8192 X 20).

OBSERVATIONS / LIMITATIONS

- For a lower number of processors, the first parallel approach was found to be (marginally) faster.

- As the number of processors increases, the alternative approach appears to be (marginally) faster. Less communication is a factor.

- Beyond a certain number of parameters (eg.20), the output does not converge adequately even after > 1000 cycles

FUTURE GOALS

- Implement in OpenMP and CUDA
- Compare performances between MPI, OpenMP and CUDA

REFERENCES

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- A comparative study of Artificial Bee Colony algorithm http://chern.ie.nthu.edu.tw/gen/comparative-study.pdf

- http://en.wikipedia.org/wiki/Artificial_bee_colony_algorithm

QUESTIONS ?

THANK YOU