Using Competing Ant Colonies to Solve k-way Partitioning Problems with Foraging and Raiding Strategies

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Abstract. The self organizing properties of ant colonies are employed to tackle the classical combinatorial optimization problem of graph partitioning. The graph is mapped onto an artificial environment in a manner that preserves the structural information. Ants from a number of colonies compete for resources. This leads to a restructuring of the global environment corresponding to a good partition. On the example graphs, this is shown to outperform the current best algorithms which are based on recursive bisection techniques.

1 Introduction

Simulation of fluid flow with the Finite Element Method approximates solution values across a domain using a set of discretized elements. In 2-Dimensional problems elements are planar polygons. Partitioning the domain for parallel processing can be mapped onto a graph partitioning problem where each vertex in the graph represents a node in the mesh, whilst an edge in the graph represents the need for communication between two nodes. The graph must be broken into approximately equal size sub-domains with as little communication between domains as possible.

There are graph partitioning problems which are NP-complete [5] and therefore we are looking for a *near optimal* partition in reasonable time. Most partitioning methods employ recursive bisection which can often provide a partition which is far from optimal [14] as regards minimizing the number of edge cuts. What seems optimal at the top level of recursion may provide a poor partition at lower levels given the benefit of hindsight. Recursive Spectral Bisection has been shown to be highly effective compared to alternative methods [13]. Multi-level implementations [8] are yet more effective especially in combination with local refinement using Kernighan Lin [9]. Recently many methods have been

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The actions and functions in this code are detailed below in Table 1. It should be noted that this foraging strategy can be generated using Genetic Programming [12].

Table 1. Actions and Functions for Main Algorithm

function/action	Explanation
if_food_ahead	Return True if food is in the adjacent square.
if_food_here	Return True if food is in the current square.
if_in_nest_locus	Return True if food is within two grid squares of the colony nest.
if_carrying_food	Return True if ant is carrying food.
if_help_signal	Return True if there is a help signal within a locus of two grid squares.
move_to_nest	Move one step towards the nest in direction: if ($ Nest.x - x \geq Nest.y - y $) then if ($x \geq Nest.x$) then $dir = WEST$ else $dir = EAST$ else if ($y \geq Nest.y$) then $dir = SOUTH$ else $dir = NORTH$.
move_to_help	Move one step towards the nearest help signal.
move_to_away_pheremone	Move one step away from the nest in the away direction with the strongest pheremone trail.
move_to_strong_forward_pheremone	Move to an adjacent square with probability dependent on the amount of pheremone present.
pick_up_food (foraging)	Food not belonging to a colony is picked up if proportion of cuts created is less than half total possible number. Number of ants needed is related to the proportion of cuts. Help signal sent out if not enough ants.
pick_up_food (raiding)	Food already in a colony is picked up with probability p dependent on the change in the proportion of cuts δp_c where $p = \begin{cases} 1.0 & \text{if } \delta p_c > 0 \\ 0.5 & \text{if } \delta p_c = 0 \\ 0.0 & \text{if } \delta p_c < -0.33 \\ 1/(2.0 * (\delta p_c)^2) & \text{if } -0.33 \leq \delta p_c < 0 \end{cases}$
drop_food	Place food around colony nest using a clockwise search for an empty cell.

3 Results

In this section the Ant Foraging Strategy (AFS) is compared with Recursive Spectral Bisection (RSB), Recursive Spectral Bisection plus Kernighan Lin (RSB

+KL) and also Multilevel Kernighan Lin (ML-KL). Each method is tested on two meshes over two, four and eight partitions. Recursive bisection (rb) and simultaneous multiple partitioning (k-way) methods are implemented in the chaco 2.0 package [6]. The number of cuts for the partitions produced are given in Table 2. Mesh 1, (114 nodes, 308 edges), is a two dimensional finite element mesh with triangular elements. Food was placed on an 18 by 18 grid and the algorithm was run for 2000 evaluations. Mesh 2, (286 nodes, 1046 edges), is a two dimensional finite element mesh with quadrilateral elements. The food was placed on a 30 by 30 grid and the algorithm was run for 5000 evaluations. The total number of ants on the grid is always equal to half the total grid area.

Table 2. Number of cuts created by various partitioning methods

Mesh	Method	RSB	RSB	KL+RSB	KL+RSB	ML-KL	ML-KL	AFS
		rb	k-way	rb	k-way	rb	k-way	k-way
1	Bisection	25	25	25	25	25	25	25
	Quadrisection	51	51	51	50	50	52	49
	Octrisection	89	103	87	97	85	95	80
2	Bisection	29	29	28	28	28	28	28
	Quadrisection	91	91	90	90	88	90	87
	Octrisection	176	195	173	191	164	187	161

4 Discussion and Further Work

The Ant Foraging Strategy shows some good results on the test meshes. It performs better than RSB, RSB+KL and ML-KL when implemented for quadrisection and octrisection i.e. simultaneous multiple partitions. It also performs better than RSB and RSB+KL when implemented for recursive bisection. Furthermore, AFS also performs better than recursive multilevel methods in most cases. AFS outperforms RSB because each partition is not dependent on partitions at higher levels of recursion. However, other multiple partitioning schemes perform poorly here. AFS performs well because it provides global structural information (by recursively placing nests) to provide a rough initial partition and a powerful local improvement technique in the form of raiding. AFS is relatively efficient compared to other swarm methods as it maps the the structure onto the environment and places nests to provide a rough initial partition quickly using a small population.

5 Conclusion

Most approaches to the k-way partitioning problem use recursive bisection and local improvement techniques, except spectral quadrisection and octrisection

which perform relatively poorly. AFS provides a novel global method for tackling the problem with built in local improvement which can simultaneously partition into as many sets as required. Results show that swarm-based simultaneous multiple partitioning needs further investigation as it can produce better partitions than recursive bisection techniques which is dependent on the partition found at higher levels of recursion. Furthermore, AFS is relatively efficient compared to other swarm-based methods and scales up well to large meshes [12] when multilevel methods are applied.

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