A Bibliography of Local Algorithms

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1. Introduction

This online bibliography is a supplement to the following survey article [108]:

> Jukka Suomela (2013). Survey of local algorithms.
> *ACM Computing Surveys*, volume 45, issue 2, article 24.

This bibliography contains the references of the original survey article, with brief annotations, as well as additional references that reflect the latest advances in the field—see Section 10 for a summary of updates. For any omitted details, please refer to the original survey. The latest version of this bibliography, as well as a link to a freely available preprint of the survey, are available online at

> http://www.cs.helsinki.fi/local-survey/

I will be happy to hear if you spot any omissions or errors.

2. Notation

The following notation is used in this work: ε is a positive constant, δ is the minimum degree of the graph, and Δ is the maximum degree of the graph. Covering and packing problems have a natural bipartite or tripartite structure, and we use the symbols Δ_K, Δ_I, and Δ_V to refer to the maximum degree of each part—see the original survey article [108] for detailed definitions.

3. Basics

3.1. Model of Computation

— Port numbering (local edge labelling) [2, 6, 122].

— Port numbering and orientation [93].

— Time = number of synchronous rounds [89].

— Local algorithm = constant-time distributed algorithm [96].

— Locally checkable labellings [96].

— Local verification and locally checkable proofs [37–40, 45, 48, 66–69].

3.2. Concepts and Techniques

— Universal covering graphs [2].

— Bipartite double covers [2, 15, 59].

— Local views [13, 122].

— Decompositions [10] and t-orientations [7].

4. Deterministic Local Algorithms

4.1. Negative Results—Anonymous Networks

— Impossibility of symmetry-breaking [2, 62, 122].

— Output is a function of the local view [2, 13, 122].

— Orientation does not help if the node degrees are even [96].

4.2. Negative Results—Unique Identifiers

See Tables 1 and 2.

— Vertex 3-colouring in an n-cycle requires $\Omega(\log^* n)$ rounds [89].

— Instance-specific advice does not help much [36].

— Not possible to find an $O(1)$-approximation of a maximum independent set in an n-cycle [18, 83, 87], [82, §11].

— A number of corollaries: edge colourings, independent sets, matchings, cuts, edge covers, vertex covers, dominating sets, domatic partitions [5, 18, 83, 87, 89, 108].

— Approximations of LPs [12, 30, 32, 35, 71, 72, 76, 79–81, 94].

— Cut minimisation and bipartite vertex cover [47].

— For a wide range of problems, unique identifiers do not help [50, 96]. Certain scheduling problems [53] are a notable exception.

4.3. Positive Results

See Tables 3 and 4.

— Weak 2-colouring [93, 96].

— Colour reduction [7, 11, 17, 44, 73, 96].

— Matchings [5, 19, 20, 34, 52].

— Vertex covers [4, 102], [94, §6.1].

— Dominating sets [5, 18, 84, 86, 87, 107], [82, §13].

— Approximations of LPs [29, 30, 32, 33, 35, 71, 72, 75, 78–80, 99].

— Scheduling problems [53].

Problem	Graph family	References
Maximal independent set	cycle	[89]
Maximal matching	cycle	[89]
Vertex 3-colouring	cycle	[89]
Vertex Δ-colouring	$(\Delta+1)$-coloured tree	[71]
Edge colouring	cycle	[89]
Weak colouring	$2k$-regular	[96]

Table 1: Problems that cannot be solved with a deterministic local algorithm, even if there are unique node identifiers.

Problem	Approximation factor	Graph family	References
Independent set	$O(1)$	cycle	[18, 82, 83, 87]
Matching	$O(1)$	general	[71, 79, 94]
	$O(1)$	cycle	[18]
Edge cover	$2-\varepsilon$	cycle	[18, 82, 83, 87]
Vertex cover	$O(1)$	general	[71, 76, 81, 94]
	$2-\varepsilon$	cycle	[18, 82, 83, 87]
	1.01	bounded-degree, 2-coloured	[46]
Dominating set	$O(1)$	general	[71, 76, 81, 94]
	$O(1)$	unit-disk	[82, 83, 87]
	$2k+1-\varepsilon$	$2k$-regular	[18]
	$k+1-\varepsilon$	$(2k+1)$-regular, 2-coloured	[5]
	$5-\varepsilon$	4-regular, planar	[18]
	$7-\varepsilon$	planar	[56]
	$3-\varepsilon$	cycle	[18, 82, 83, 87]
Domatic partition	$3-\varepsilon$	cycle	[18, 82, 83, 87]
Edge dominating set	$3-\varepsilon$	cycle	[18, 82, 83, 87]
	$4-1/k-\varepsilon$	$2k$-regular	[49]
Maximum cut	$O(1)$	cycle	[18, 82, 83, 87]
Set cover	$k-\varepsilon$	k-regular	[3, 18, 82, 83, 87]
0/1 packing LP	$O(1)$	general	[71, 79, 94]
0/1 covering LP	$O(1)$	general	[71, 76, 81, 94]
0/1 max-min LP	$\Delta_I(1-1/\Delta_K)$	bounded-degree	[30, 32, 35]

Table 2: Approximation factors that cannot be achieved with a deterministic local algorithm, even if there are unique node identifiers.

Problem	Graph family	Model	References
Maximal matching	bicoloured, B-D	P	[52]
ε-stable matching	bicoloured, B-D	P	[34]
Vertex $(\Delta+1)$-colouring	k-coloured, B-D	P	[11, 17, 44, 73]
Weak colouring	odd degree, B-D	P+O	[93, 96]

B-D	graphs with node degrees at most Δ
P	algorithm uses only a port numbering
P+O	algorithm uses only a port numbering and an orientation

Table 3: Deterministic local algorithms.

Problem	Approximation factor	Tight result	Graph family	Model	References
Matching	$1+\varepsilon$	$*$	2-coloured, B-D	P	[5, 52]
	$(\Delta+1)/2$	$*$	W-C, B-D	P	[5]
Weighted matching	$2+\varepsilon$		2-coloured, B-D	P	[34]
Simple 2-matching	$2+\varepsilon$		B-D	P	[5, 102]
Semi-matching	$O(1)$		2-coloured, B-D	P	[19]
	2		2-coloured, B-D	P	[20]
Edge cover	2	$*$	general	P	
Vertex cover	2	$*$	regular	P	
	6		unit-disk	P	[71, 117]
	$4+\varepsilon$		B-D		[94]
	3		B-D	P	[102]
	$2+\varepsilon$		B-D		[71, 79]
	2	$*$	B-D	P	[3, 4]
Dominating set	$\Delta+1$		B-D	P	
	$2\lfloor\Delta/2\rfloor+1$	$*$	B-D	P+O	[5]
	$(\Delta+1)/2$	$*$	W-C, B-D	P	[5]
	52		planar		[18, 82, 86, 87, 115]
	636		planar	P	[114]
	$O(A\log\Delta)$		B-A, B-D	P	[82, 84, 87]
Domatic partition	$(\delta+1)/2$		W-C, B-D	P	
Edge dominating set	$4-2/\Delta$	$*$	B-D	P	[107]
Maximum cut	Δ		W-C, B-D	P	
MAX-SAT	2				
Set cover	Δ_V	$*$	B-D	P	
	$\Delta_K+\varepsilon$		B-D		[71, 79]
	Δ_K	$*$	B-D	P	[3]
Packing LP	Δ_I		B-D	P	[99]
0/1 packing LP	$1+\varepsilon$	$*$	B-D		[71, 79]
0/1 covering LP	$1+\varepsilon$	$*$	B-D		[71, 79]
Max-min LP	Δ_I		B-D	P	[99]
	$\Delta_I(1-1/\Delta_K)+\varepsilon$	$*$	B-D	P	[29, 30, 32, 33, 35]
Fractional colouring	$\Delta+1+\varepsilon$		B-D		[53]

B-D	graphs with node degrees at most Δ
B-A	graphs with arboricity at most A
W-C	a weak 2-colouring is given (or can be found locally)
P	algorithm uses only a port numbering
P+O	algorithm uses only a port numbering and an orientation

Table 4: Deterministic local approximation algorithms.

5. Randomised Local Algorithms

5.1. Negative Results

— Amplification of failure probability [71, §4.5].

— Randomness does not help with local graph colouring [71, 89, 95].

— Randomness does not help with locally checkable labellings [96].

— Randomness does not help with linear programs [71, §2.7.1].

— Vertex cover in bipartite graphs does not admit randomised local approximation schemes [47].

— Lower bounds for independent sets [42].

5.2. Positive Results

— Matchings [58, 97, 112].

— Independent sets [18].

— Randomised LP rounding [71, 75, 78–80]: expected approximation factor $O(\log \Delta)$ for dominating sets, $O(\Delta)$ for independent sets.

6. Local Algorithms for Geometric Problems

6.1. Partial Geometric Information

— LP approximations [71, 77].

— Scheduling problems [28, 31].

6.2. Full Geometric Information

— Tiling strategy: partition the plane into rectangles, and colour the rectangles with a constant number of colours [54, 55, 71, 77, 94, 116, 118, 121].

— Colouring [7, 10, 55, 71, 104, 116, 121].

— Vertex covers [54, 55, 116–118, 120].

— Dominating sets [21, 54, 55, 74, 116, 117, 119].

— Independent sets [7, 10, 55, 116, 117, 120].

— Maximal matchings [55, 118].

— Scheduling problems [64].

6.3. Constructing Planar Subgraphs

— Planar subgraphs: Gabriel graphs [41] and relative neighbourhood graphs [61, 109].

— Spanners: Yao graphs [123] and θ-graphs [65].

— Bounded-degree spanners [16, 63, 88, 111, 113].

— Coloured subgraphs [22, 23, 110, 116, 121].

7. Applications

- Converting deterministic local algorithms into self-stabilising algorithms [8, 9, 85].
- Converting local algorithms into constant-time centralised algorithms [34, 97, 100].
- Lower bounds for local algorithms imply lower bounds in the tile-assembly model [105].
- Geographic routing [14, 43, 70, 124].

8. Related Work

- Distributed algorithms in general [26, 92, 101].
- Impossibility results in general [27, 91].
- Self-stabilising algorithms [24, 25, 103].
- Randomised distributed algorithms [1, 60, 90].
- Randomised algorithms with non-constant guarantees [71, §4.5].
- Value of information [98, 99].

9. Open Problems

There has been some recent progress on the open problems given in the survey [108, Section 10]:

- Problem 3 (the role of unique identifiers) is now much better understood [50, 53].
- Problem 4 (complexity as a function of Δ) is still open, but some $\Omega(\Delta)$ lower bounds have been presented recently [51, 57].

10. Timeline of Updates

- From SIROCCO 2012: [53].
- From PODC 2012: [49, 57].
- From DISC 2012: [20, 39, 46].
- From OPODIS 2012: [38].
- From PODC 2013: [40, 114].
- From ITCS 2014: [42].
- From PODC 2014: [51, 56].
- Journal papers published in 2013: [47, 50, 87].
- Journal papers published in 2014: [48, 115].

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