Grid-Based Path Planning Competition Results*

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SoCS 2012

*more results coming soon

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What is the GPPC?

- A large number of papers have been published on path planning in grids
  - Most papers do not compare to existing techniques
- What is the best approach?

GPPC

- By holding a competition:
  - Other people provide code with a common API
  - Test code on a common machine
  - Test code on common problems

GPPC - Who wins?

- Many different metrics for comparing code:
  - Memory usage
  - Optimality
  - Speed
    - Max time per action [real time]
    - Time to get first moves [incremental]
    - Overall

GPPC - caveat

- I didn't enter the competition
  - I choose the maps
  - I choose the metrics
  - I run everyone's code

  - I don't have time!

GPPC Entry: CPD

Institution(s)	IBM Research, Dublin/ANU/NICTA
Participants	Adi Botea
Title	Compressed Path Databases
Description	Compute directions for APSP data and compress resulting table.

GPPC Entry: JPS

Institution(s)	ANU/NICTA
Participants	Daniel Harabor, Alban Grastien
Title	Jump Point Search
Description	Advanced symmetry detection in grid worlds Online and offline versions

GPPC Entry: MCA

Institution(s)	University of Macedonia, Thessaloniki, Greece
Participants	Ioannis Papikas, Ioannis Refanidis
Title	Manhattan Cohesive Areas
Description	Divide map into areas where a perfect heuristic exists and subgoal searches between areas.

GPPC Entry: PDH

Institution(s)	Universidad Carlos III de Madrid
Participants	Álvaro Parra, Álvaro Torralba, Carlos Linares López
Title	Precomputed Direction Heuristics
Description	World abstracted into regions & distance between regions stored

GPPC Entry: PPQ

Institution(s)	University of New South Wales
Participants	Dr Jose Guivant, Brett Seton, Mark Whitty
Title	Pseudo-priority queues
Description	Faster way for quickly accessing best node on OPEN

GPPC Entry: SUB

Institution(s)	USC Universidad Católica de la Ssma. Concepción
Participants	Tansel Uras, Carlos Hernández, Sven Koenig
Title	Subgoal Graphs for Eight-Neighbor Gridworlds
Description	Subgraph of regions with perfect heuristics

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GPPC Entry: Tree

Institution(s)	-
Participants	Ken Anderson
Title	Tree Cache
Description	Connect world with tree & cache paths in tree

GPPC Entry: BFS

Institution(s)	-
Participants	(GPPC Sample Code)
Title	BFS
Description	Breadth-first search with unit edge costs

GPPC Entry: Block A*

Institution(s)	University of Alberta
Participants	Peter Yap, Neil Burch
Title	Block A*
Description	Pre-computes all 3x3 paths and searches in 3x3 blocks

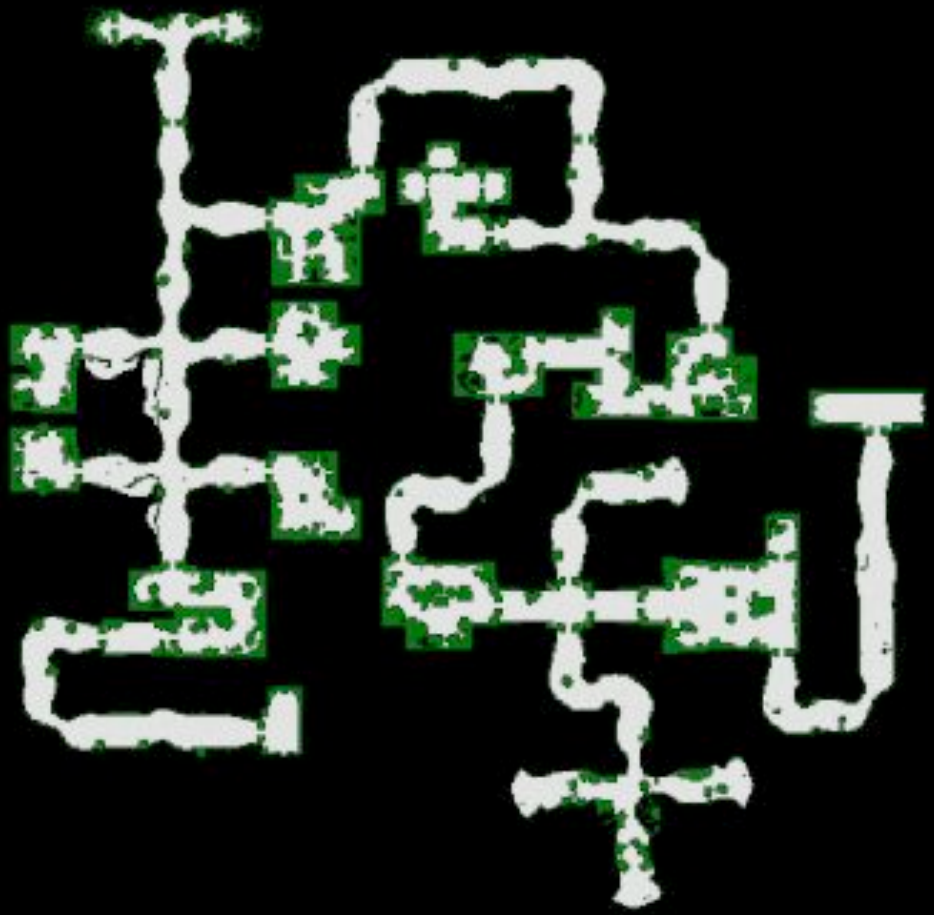
Missing entry types

- Abstraction/refinement (cache)
- Better heuristics

GPPC Process

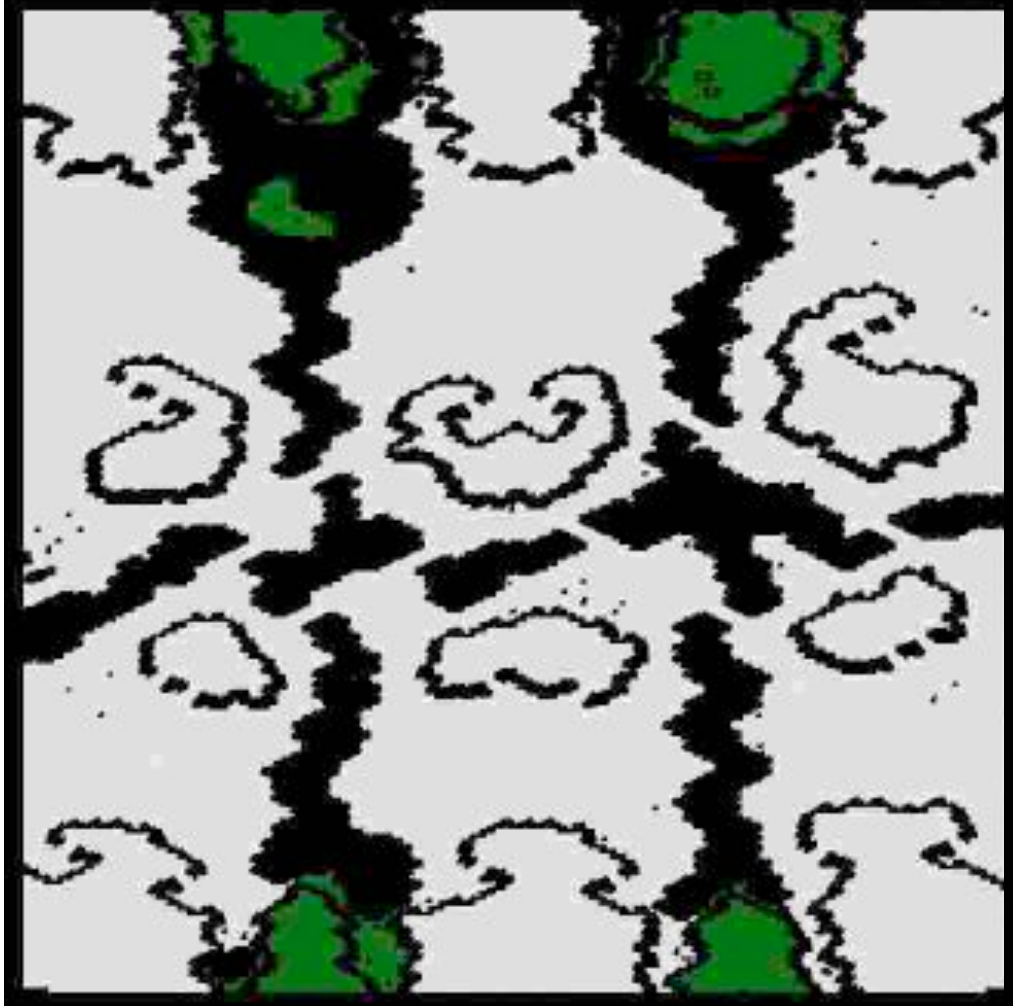
- 132 maps
  - 27 from Dragon Age: Origins
  - 67 (all) from Dragon Age II
  - 11 from Starcraft
  - 9 artificial maps each in {mazes, rooms, random}

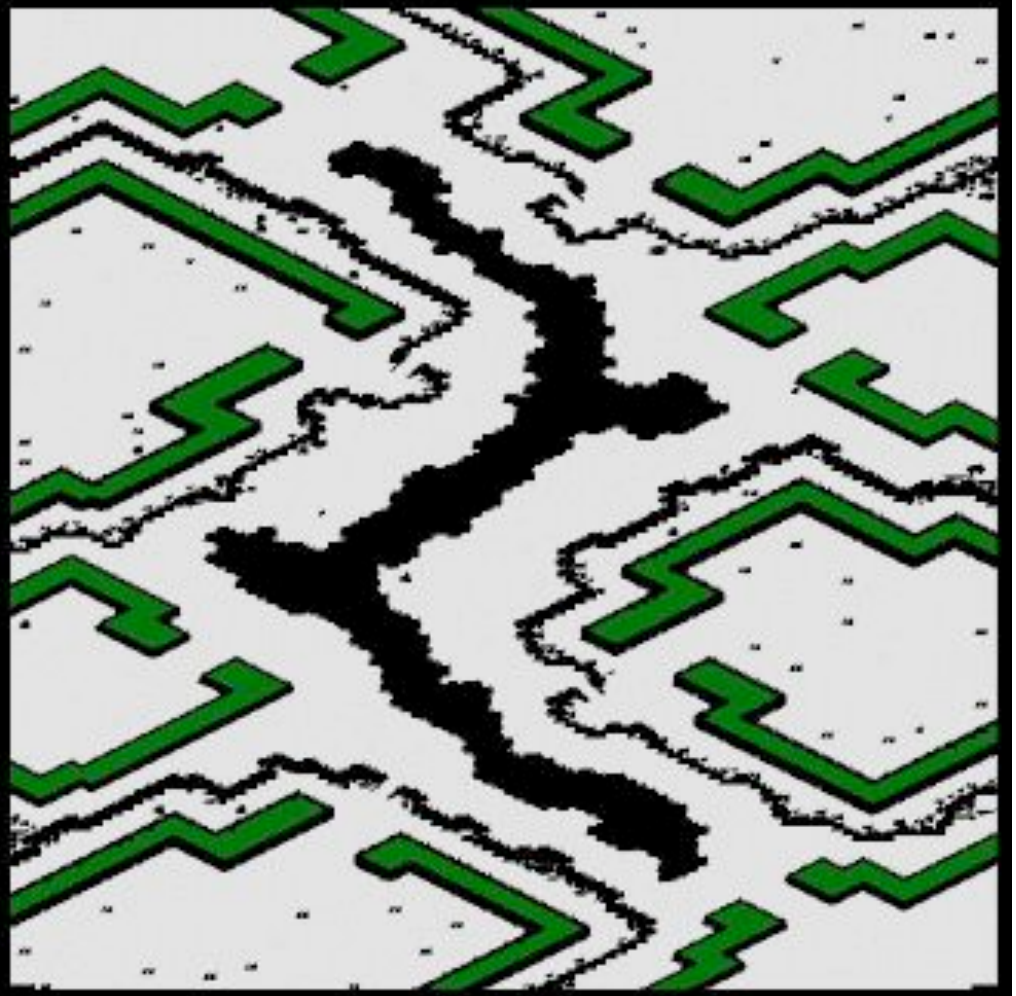
Dragon Age: Origins



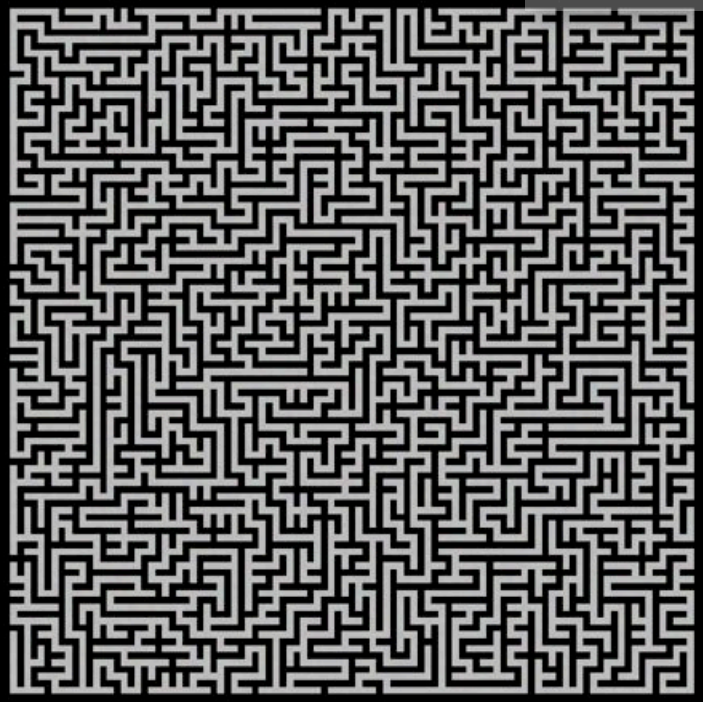
Dragon Age 2

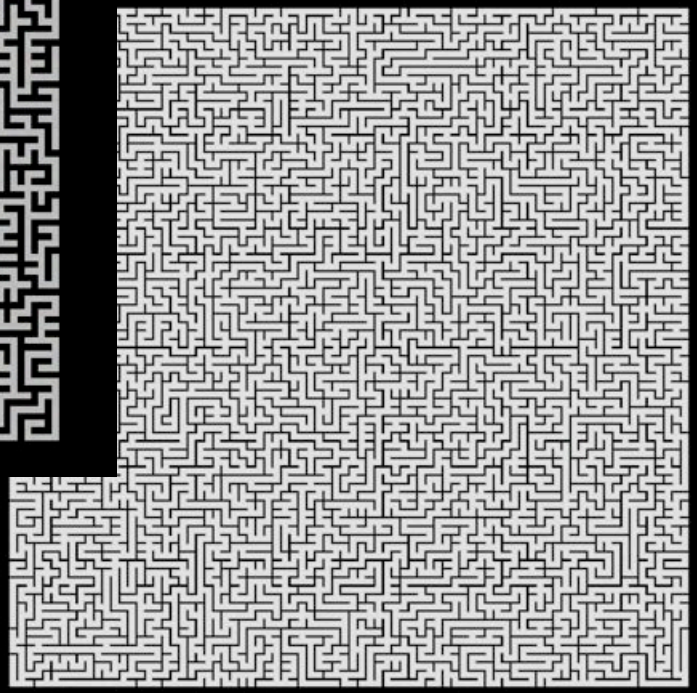
Starcraft

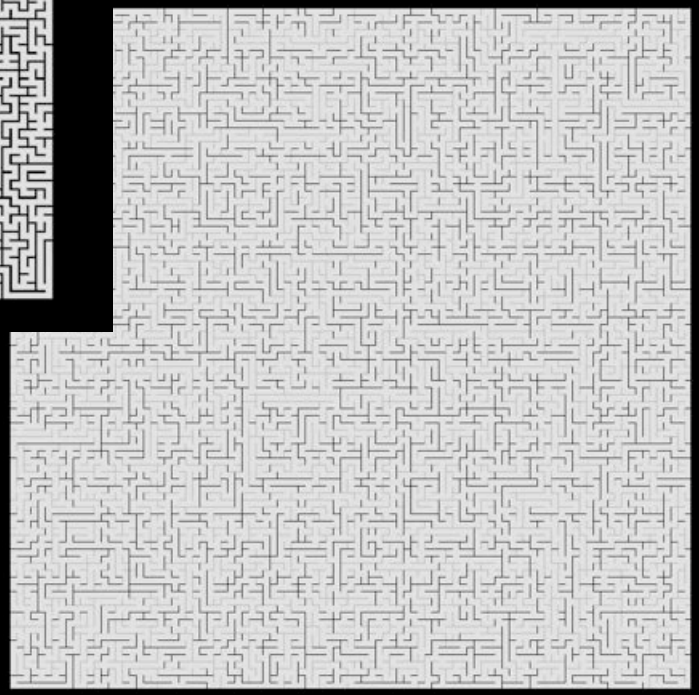




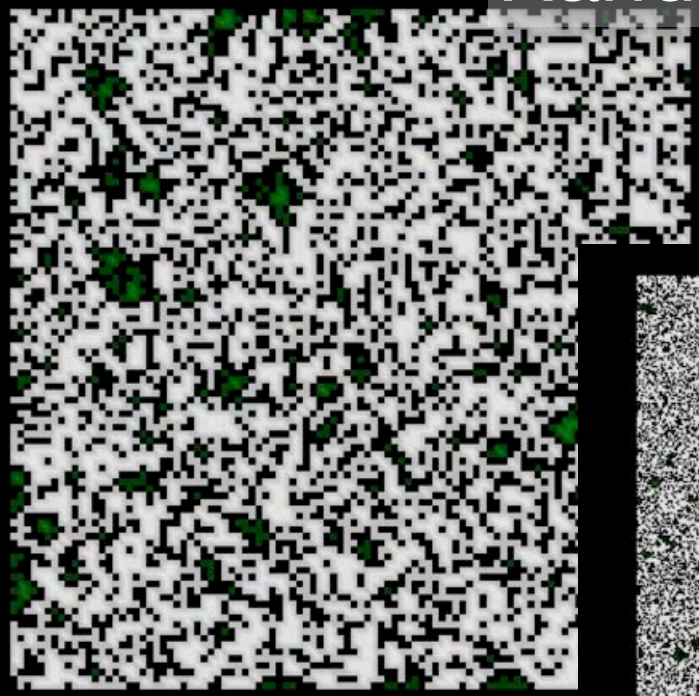
Maze - 1% corridor size

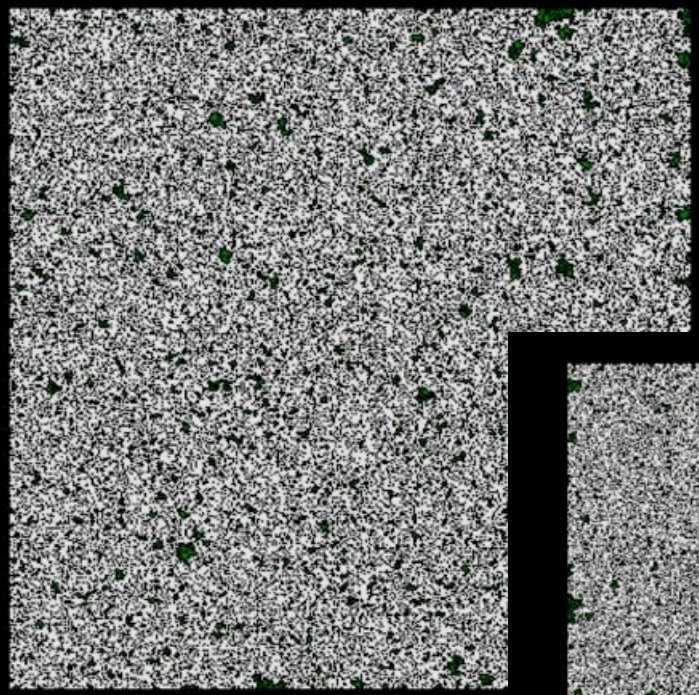


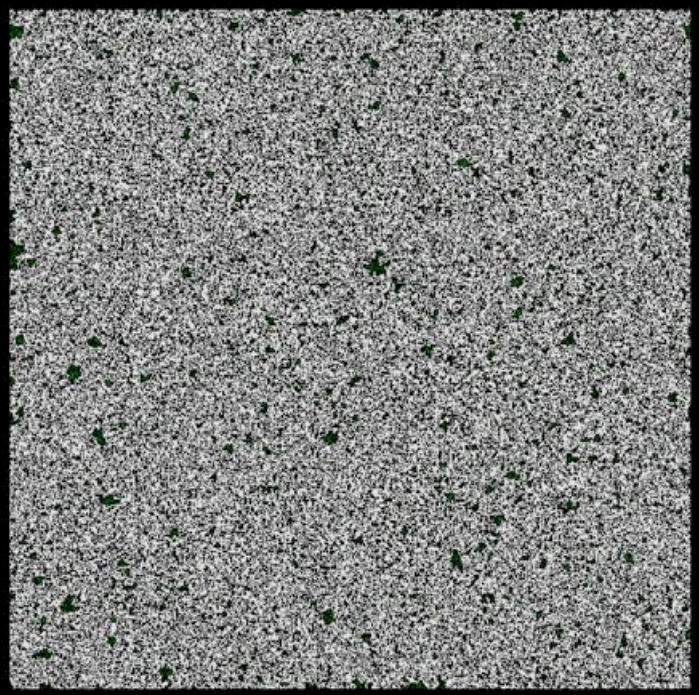




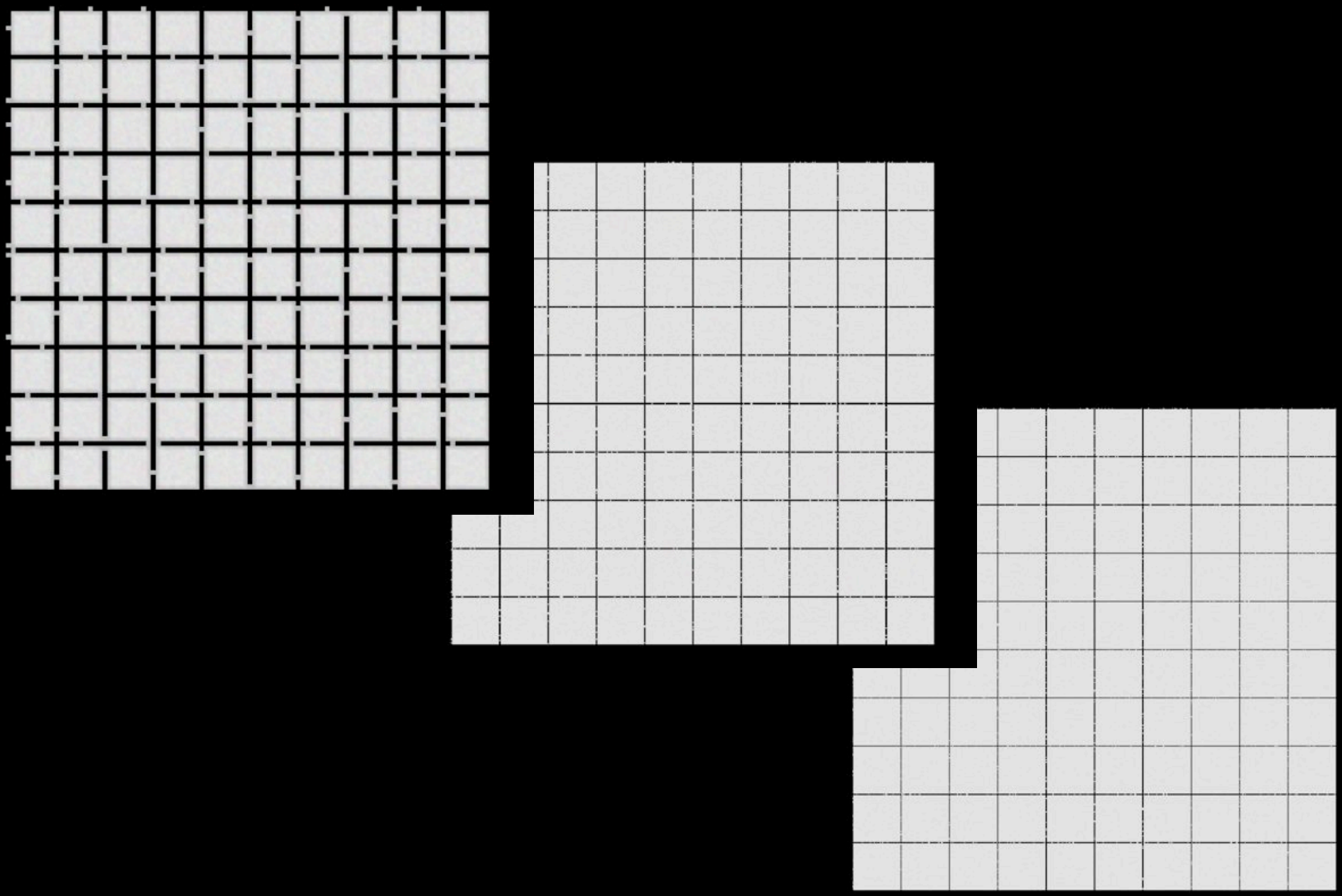
Random - 33% obstacles







Room - Multiple doors



Testing

- 1,740,660 total paths tested
  - 348,132 problems
  - 5 runs
- Results averaged over:
  - 5 runs on each map
  - Each map set / all maps

Failure

- Only three entries ran all maps
  - One entrant knew ahead of time that the approach wouldn’t run on large maps
- Some entries failed on just a few problems
- Some entries had larger failures

Failures

BlockA*	Maps 950x950 or larger
CPD	Large maps (artificial benchmarks)
MCA	Many [*some fixed*]
Tree	20 random maps [*fixed*]
PPQ	23 problems (0.0066%)
JPS	Pre-computation at runtime

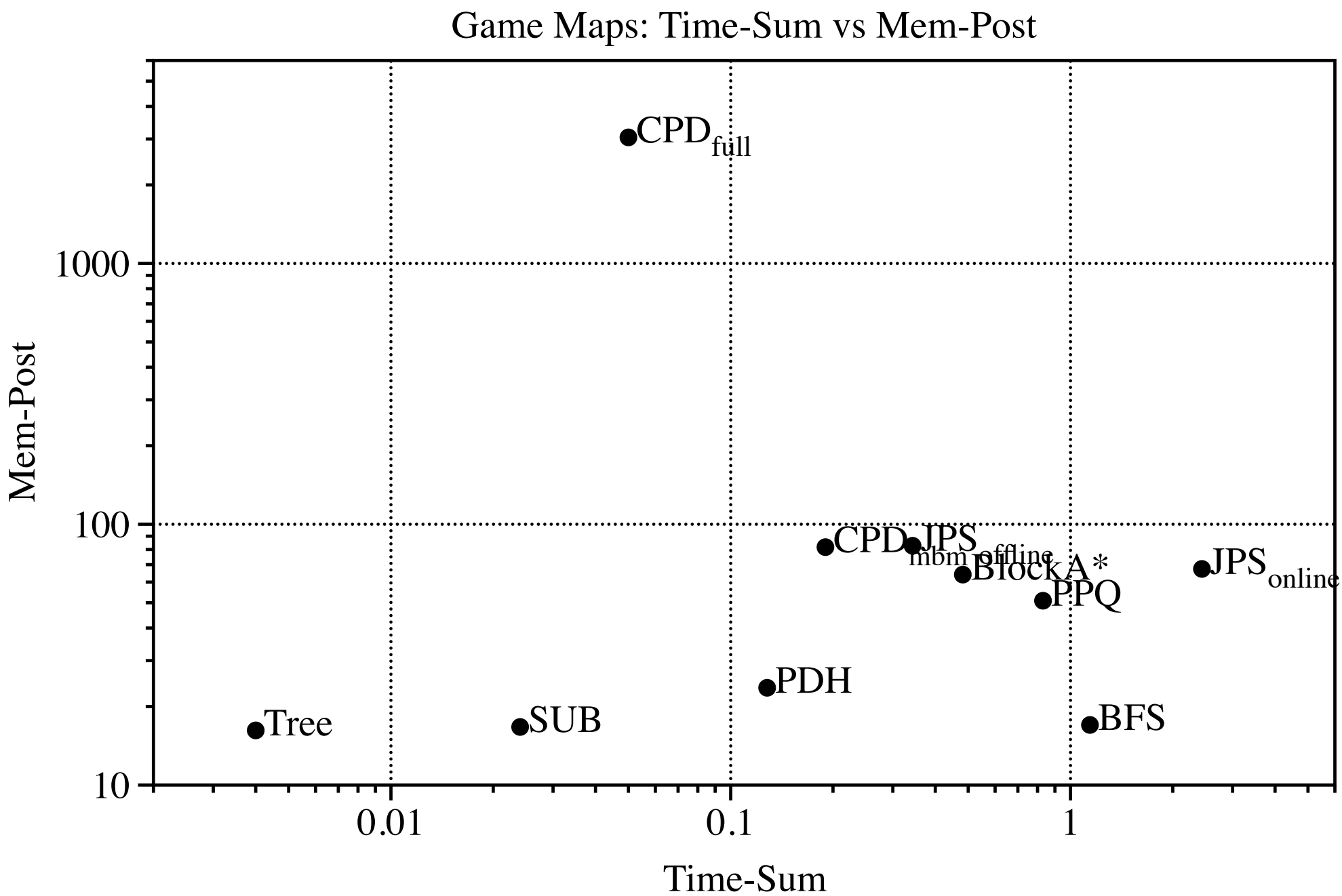
Map Set: All

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.5**	47.5	7.373	7.372	7.372	612.6	1.16
BlockA*							
CPD_{full}							
CPD_{mbm}							
$JPS_{offline}$	360.3	385.6	9.596	9.596	9.596	**530.3**	**1.00**
JPS_{online}	251.4	278.2	21.991	21.991	21.991	**530.3**	**1.00**
MCA							
PDH	19.4	50.9	0.130	0.009	0.015	598.7	1.16
PPQ	47.3	73.5	5.199	5.199	5.199	532.3	1.00
SUB	16.5	43.0	0.662	0.662	0.662	**530.3**	**1.00**
Tree	12.3	**42.8**	**0.009**	**0.009**	**0.009**	637.8	1.65

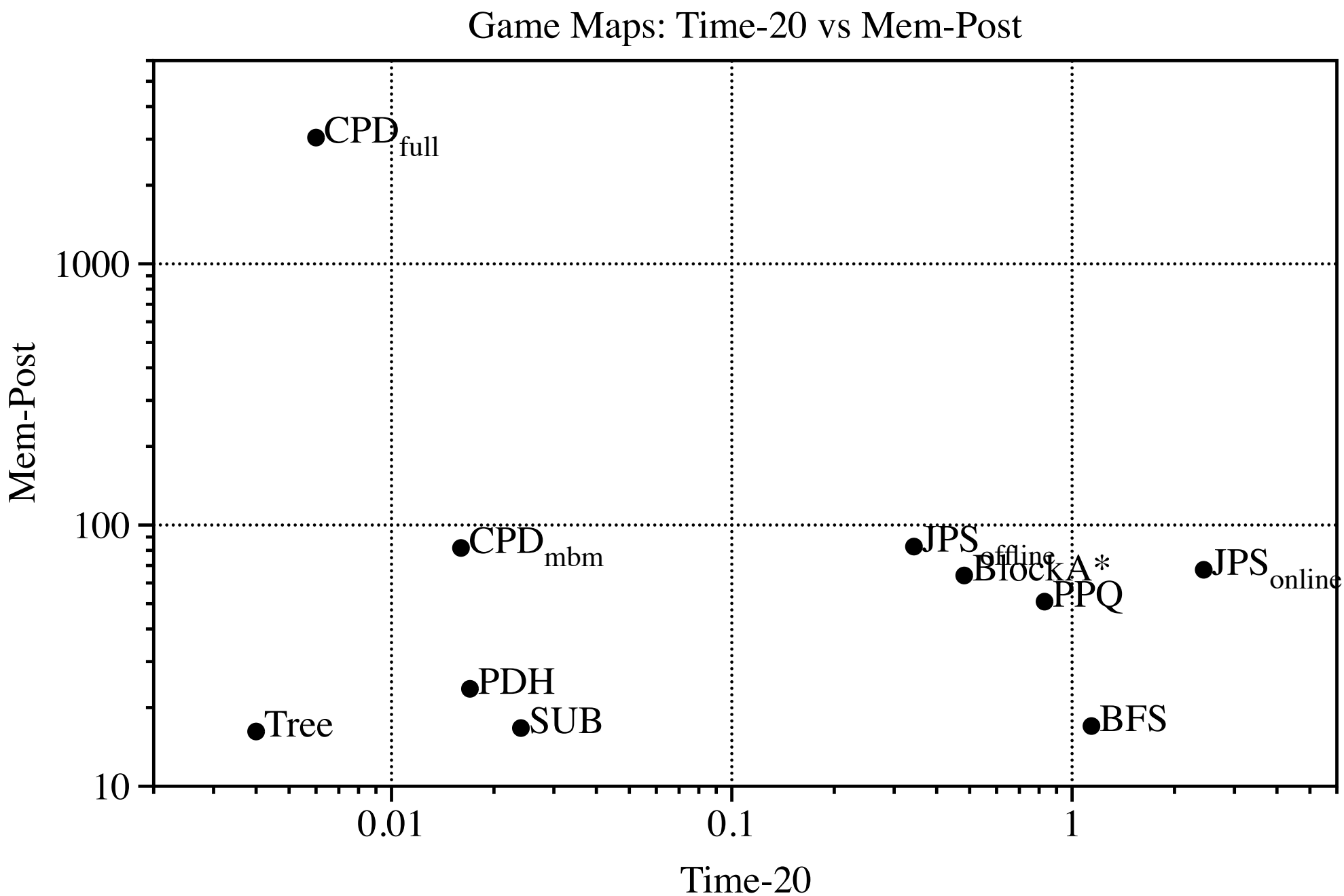
Map Set: Game Maps

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.5**	17.0	1.141	1.140	1.140	298.3	1.15
BlockA*	58.0	64.1	0.482	0.482	0.482	298.3	1.15
CPD_{full}	3040.1	3043.2	0.050	0.045	0.006	**258.7**	**1.00**
CPD_{mbm}	67.8	81.7	0.190	0.006	0.016	**258.7**	**1.00**
$JPS_{offline}$	79.7	82.7	0.343	0.343	0.343	**258.7**	**1.00**
JPS_{online}	63.5	67.4	2.437	2.437	2.437	**258.7**	**1.00**
MCA							
PDH	17.7	23.6	0.128	0.009	0.017	302.8	1.16
PPQ	47.3	50.9	0.830	0.830	0.830	259.1	1.00
SUB	12.8	16.7	0.024	0.024	0.024	**258.7**	**1.00**
Tree	11.9	**16.2**	**0.004**	**0.004**	**0.004**	303.6	1.51

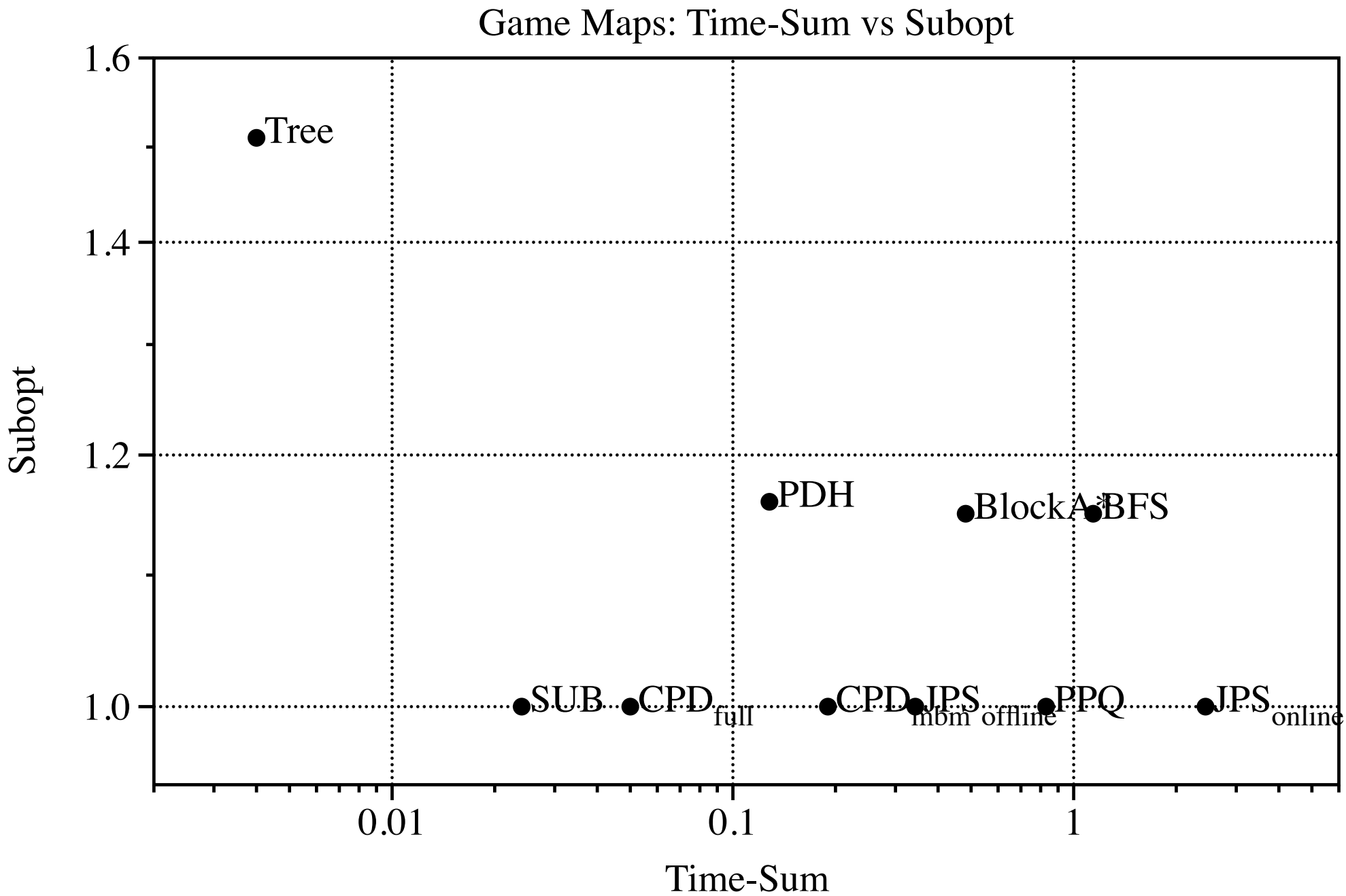
All Solvers


Game Maps: Time-Sum vs Mem-Post
CPD full
CPD
JPS mbm offline
BlockA*
PPQ
JPS online
PDH
Tree
SUB
BFS
1000
100
10
0.01
0.1
1
Mem-Post
Time-Sum

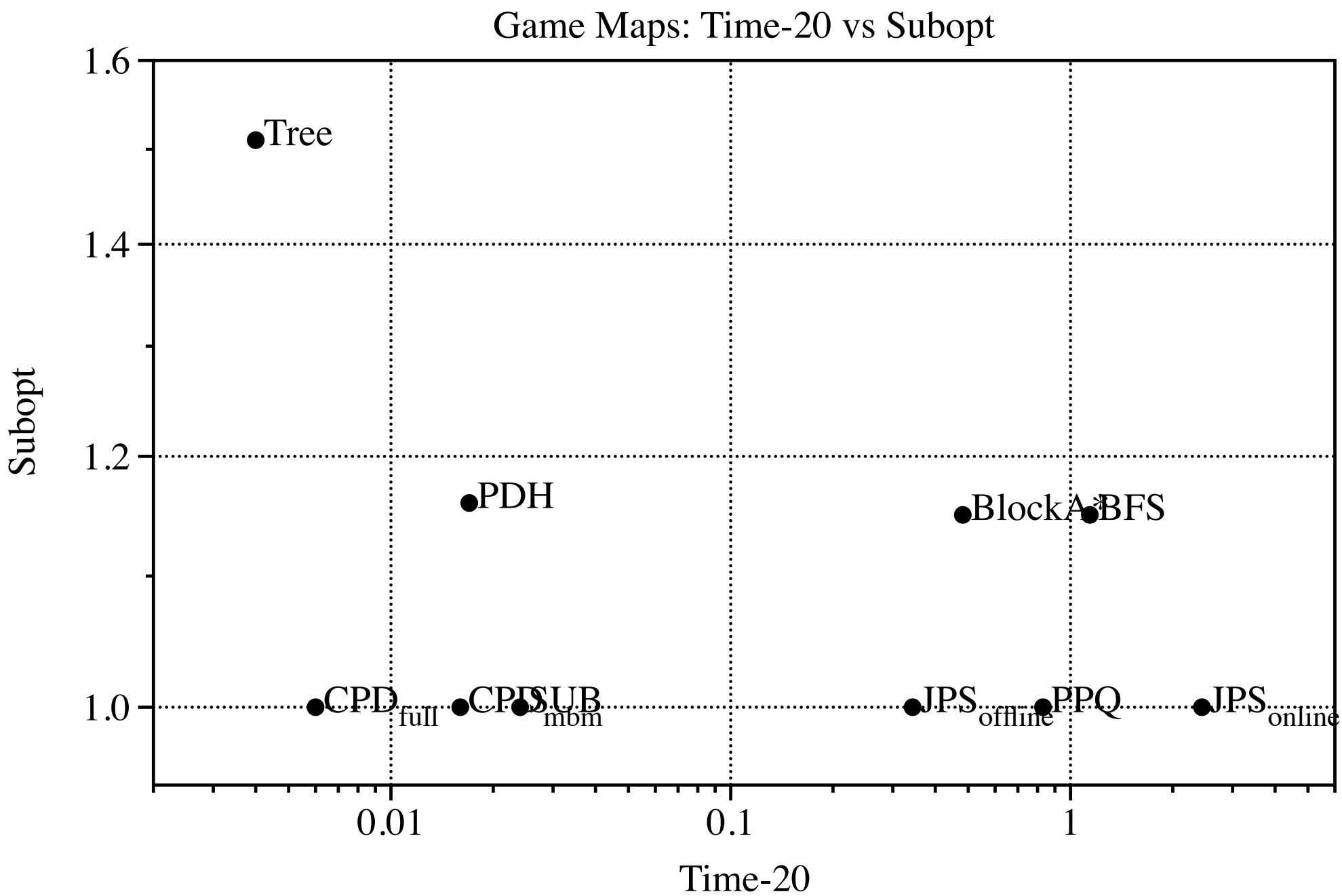
All Solvers


Game Maps: Time-20 vs Mem-Post
CPD full
CPD mbm
JPS offline
BlockA*
JPS online
PPQ
PDH
SUB
Tree
BFS
1000
100
10
0.01
0.1
1
Mem-Post
Time-20

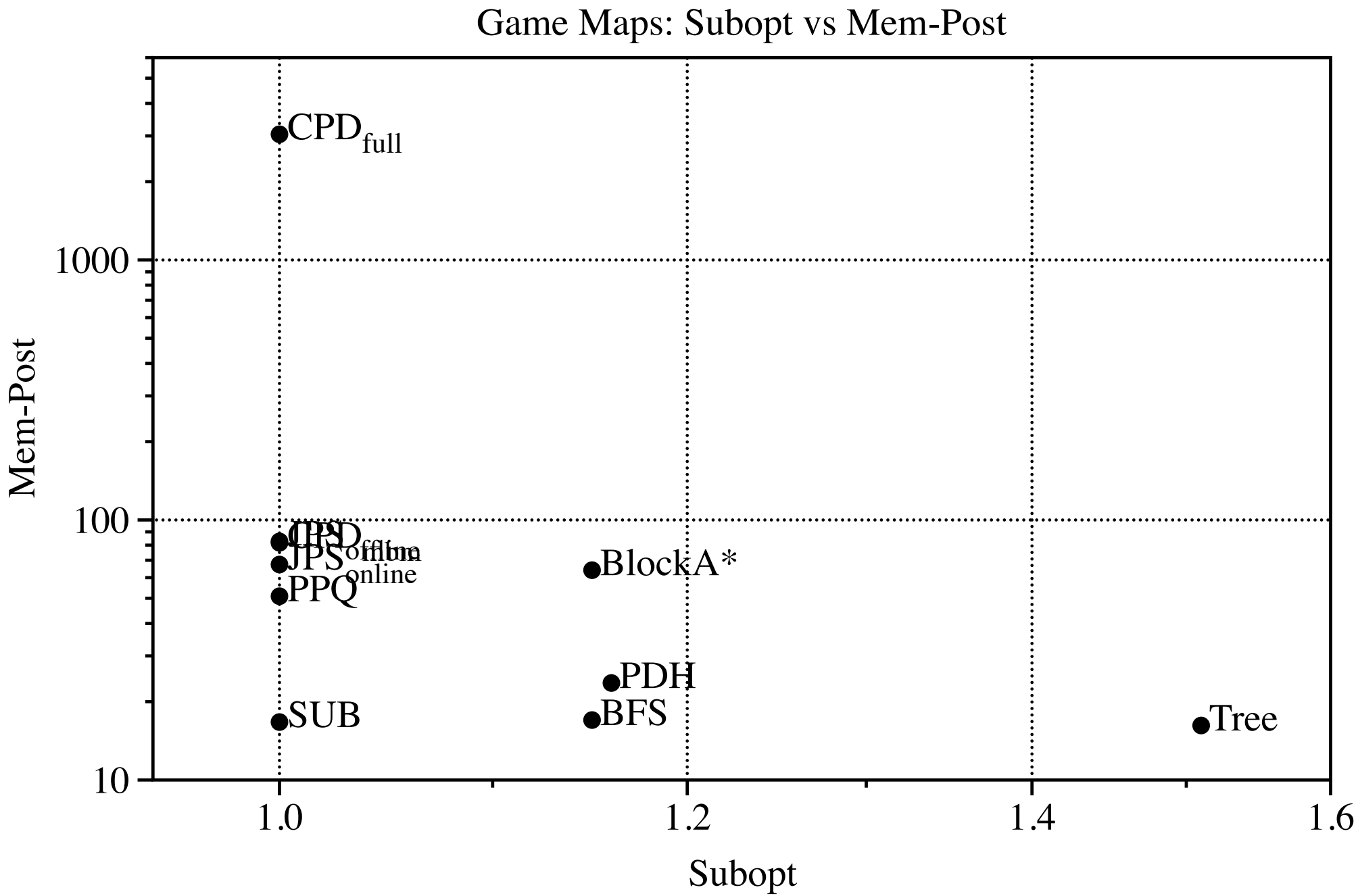
All Solvers


Game Maps: Time-Sum vs Subopt
1.6
1.4
1.2
1.0
Subopt
Tree
PDH
BlockA*
BFS
SUB
CPD full
CPD
JPS mbm
offline
PPQ
JPS online
0.01
0.1
1
Time-Sum

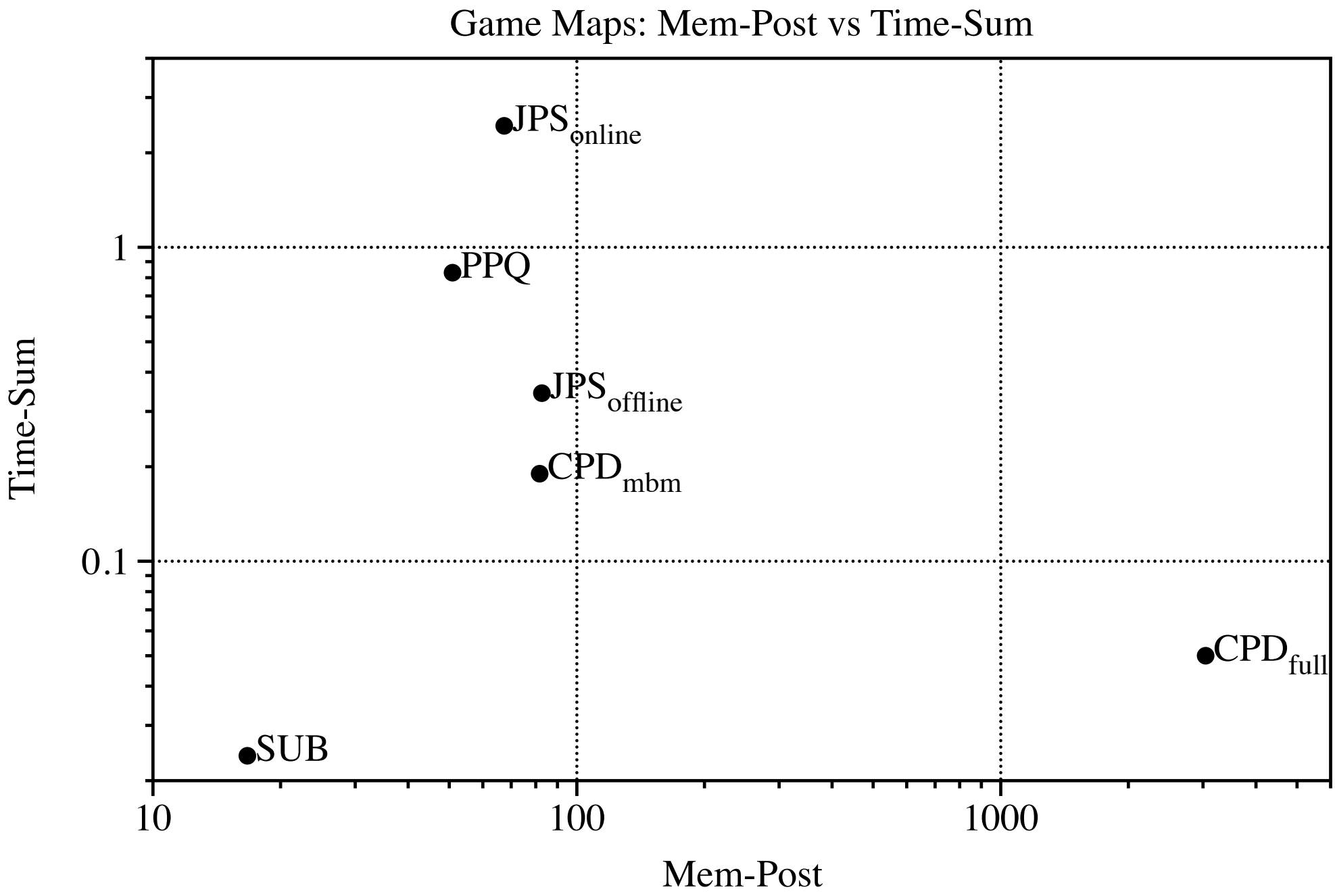
All Solvers


Game Maps: Time-20 vs Subopt
Subopt
Time-20
1.6
1.4
1.2
1.0
0.01
0.1
1
Tree
PDH
BlockA*
BFS
CPD full
CPDS
SUB mbm
JPS offline
PPQ
JPS online

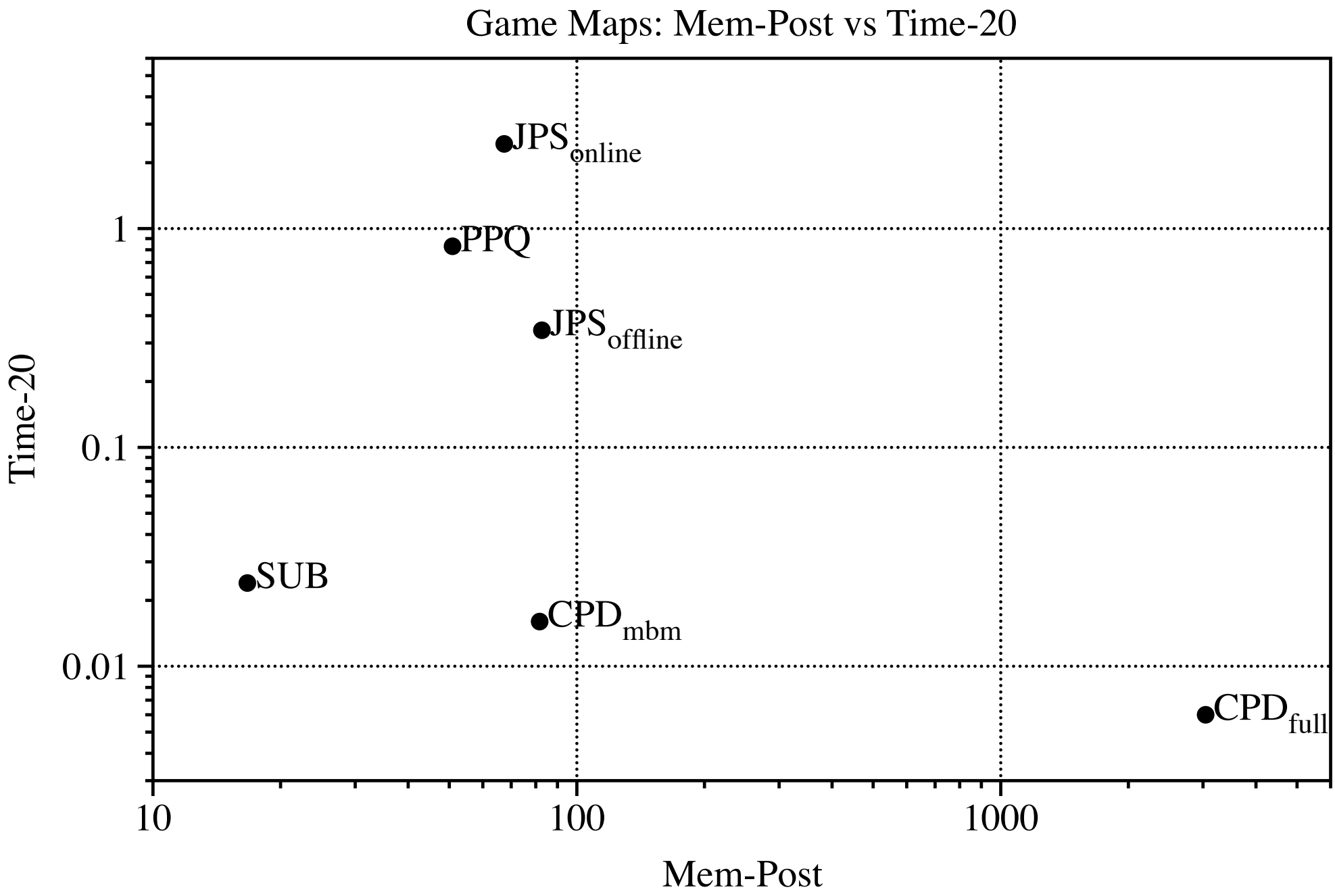
All Solvers


Game Maps: Subopt vs Mem-Post
CPD full
CPD offline
JPS online
JPS online
PPQ
BlockA*
PDH
SUB
BFS
Tree
1000
100
10
1.0
1.2
1.4
1.6
Mem-Post
Subopt

Optimal Solvers



Optimal Solvers



Map Set: DAO

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.5**	21.0	1.050	1.049	1.049	374.7	1.15
BlockA*	59.8	69.9	0.581	0.581	0.581	374.7	1.15
CPD_{full}	2231.3	2237.0	0.060	0.056	**0.005**	**329.3**	**1.00**
CPD_{mbm}	50.2	76.6	0.242	0.007	0.015	**329.3**	**1.00**
$JPS_{offline}$	77.0	83.5	0.461	0.461	0.461	**329.3**	**1.00**
JPS_{online}	63.2	70.3	3.201	3.201	3.201	**329.3**	**1.00**
MCA							
PDH	18.1	28.8	0.137	0.011	0.018	387.2	1.14
PPQ	47.3	54.1	0.823	0.823	0.823	330.1	1.00
SUB	12.9	19.9	0.024	0.024	0.024	**329.3**	**1.00**
Tree	12.0	**19.5**	**0.005**	**0.005**	0.005	372.3	1.62

Map Set: DA2

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.5**	14.5	0.566	0.565	0.565	237.8	1.15
BlockA*	56.4	60.0	0.252	0.252	0.252	237.8	1.15
CPD_{full}	3307.7	3309.3	0.037	0.031	0.006	**207.4**	**1.00**
CPD_{mbm}	29.7	36.7	0.149	0.005	0.016	**207.4**	**1.00**
$JPS_{offline}$	48.4	49.6	0.167	0.167	0.167	**207.4**	**1.00**
JPS_{online}	40.3	42.3	0.972	0.972	0.972	**207.4**	**1.00**
MCA							
PDH	17.3	20.6	0.127	0.009	0.017	241.1	1.17
PPQ	47.3	49.1	0.434	0.434	0.434	207.6	1.00
SUB	12.2	14.3	0.020	0.020	0.020	**207.4**	**1.00**
Tree	11.8	**14.0**	**0.004**	**0.004**	**0.004**	239.2	1.43

Map Set: SC

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.6**	26.1	8.394	8.393	8.393	667.8	1.21
BlockA*	68.6	85.0	2.617	2.617	2.617	667.8	1.21
CPD_{full}	3757.5	3764.9	0.170	0.158	0.013	**548.9**	**1.00**
CPD_{mbm}	592.0	625.5	0.447	0.010	0.022	**548.9**	**1.00**
$JPS_{offline}$	469.2	475.7	1.700	1.700	1.700	**548.9**	**1.00**
JPS_{online}	346.3	355.5	15.702	15.702	15.702	**548.9**	**1.00**
MCA							
PDH	20.3	33.0	0.097	**0.007**	**0.008**	663.0	1.23
PPQ	47.3	56.1	5.550	5.550	5.550	550.2	1.00
SUB	19.4	28.6	0.071	0.071	0.071	**548.9**	**1.00**
Tree	12.5	**24.5**	**0.009**	0.009	0.009	735.5	1.80

Map Set: Random

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.7**	36.8	29.79	29.79	29.79	802.5	1.11
BlockA*							
CPD_{full}							
CPD_{mbm}							
$JPS_{offline}$	1076.0	1090.8	124.22	124.22	124.22	**719.8**	**1.00**
JPS_{online}	582.0	603.5	119.63	119.63	119.63	**719.8**	**1.00**
MCA							
PDH	25.7	47.8	0.09	**0.01**	**0.01**	865.6	1.20
PPQ	47.5	65.1	23.53	23.53	23.53	729.5	1.01
SUB	32.7	50.3	9.21	9.21	9.21	**719.8**	**1.00**
Tree	13.7	**36.7**	**0.02**	0.02	0.02	922.4	1.88

Map Set: Room

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.7**	**31.4**	32.017	32.016	32.016	744.2	1.21
BlockA*							
CPD_{full}							
CPD_{mbm}							
$JPS_{offline}$	1582.3	1590.9	4.183	4.183	4.183	**606.9**	**1.00**
JPS_{online}	1145.7	1157.6	94.125	94.125	94.125	**606.9**	**1.00**
MCA							
PDH	25.7	40.6	0.074	**0.008**	**0.010**	719.2	1.20
PPQ	47.5	59.3	18.813	18.813	18.813	621.6	1.02
SUB	29.1	40.8	0.095	0.095	0.095	**606.9**	**1.00**
Tree	13.7	33.1	**0.013**	0.013	0.013	1012.8	2.49

Map Set: Mazes

Entry	Memory (MB)		Time (ms)			Length	
	Pre	Post	Total	Max	20	Tot	%
BFS	**11.7**	425.8	28.71	28.71	28.71	3727.8	1.13
BlockA*							
CPD_{full}							
CPD_{mbm}							
$JPS_{offline}$	1461.8	1771.7	7.64	7.64	7.64	**3247.6**	**1.00**
JPS_{online}	1046.7	1358.3	72.75	72.75	72.75	**3247.6**	**1.00**
MCA							
PDH	25.7	378.5	0.27	**0.01**	**0.01**	3429.7	1.05
PPQ	47.5	356.8	21.43	21.43	21.43	3247.8	1.00
SUB	27.3	**338.6**	0.10	0.10	0.10	**3247.6**	**1.00**
Tree	13.7	365.2	**0.04**	0.04	0.04	3622.8	2.16

Summary: Game Benchmarks

- Fastest:
  - Tree Cache, Ken Anderson
- Best Optimal:
  - SUB, Tansel Uras, Carlos Hernández, Sven Koenig
  - CPD, Adi Botea
- Other non-dominated approaches
  - PDH, Álvaro Parra, Álvaro Torralba, Carlos Linares López
  - BFS

Conclusions

- GPPC is needed!
- Availability of benchmarks and competition results should help research
- Good start to competition
- Open question:
  - Should new tracks be available next year?