Chapter 10: Customizing Search (Progressive Party Problem)

Helmut Simonis

Cork Constraint Computation Centre Computer Science Department University College Cork Ireland

ECLiPSe ELearning Overview



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Outline

- Problem
- 2 Program
- Search
- A Further Decomposition



What we want to introduce

- Problem decomposition
 - Decide which problem to solve
 - Not always required to solve complete problem in one go
- Modelling with bin packing
- Customized search routines can bring dramatic improvements
- Understanding what is happening important to find improvements





Outline

- Problem
 - Phase 1
 - Phase 2
- Program
- Search
- A Further Decomposition





Problem Definition

Progressive Party

The problem is to timetable a party at a yacht club. Certain boats are to be designated hosts, and the crews of the remaining boats in turn visit the host boats for several successive half-hour periods. The crew of a host boat remains on board to act as hosts while the crew of a guest boat together visits several hosts. Every boat can only host a limited number of guests at a time (its capacity) and crew sizes are different. The party lasts for 6 time periods. A guest boat cannot not revisit a host and guest crews cannot meet more than once. The problem facing the rally organizer is that of minimizing the number of host boats.

ork raint ation



Data

Boat	1	2	3	4	5	6	7	8	9	10	-11	12	13	14
Capacity	6	8	12	12	12	12	12	10	10	10	10	10	8	8
Crew	2	2	2	2	4	4	4	1	2	2	2	3	4	2
Boat	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Capacity	8	12	8	8	8	8	8	8	7	7	7	7	7	7
Crew	3	6	2	2	4	2	4	5	4	4	2	2	4	5
Boat	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Capacity	6	6	6	6	6	6	6	6	6	6	9	0	0	0
Crew	2	4	2	2	2	2	2	2	4	5	7	2	3	4



High Level Problem Decomposition

- Phase 1: Select minimal set of host boats
 - Manually
- Phase 2: Create plan to assign guest boats to hosts in multiple periods
 - Done as a constraint program





Idea

- Decompose problem into multiple, simpler sub problems
- Solve each sub problem in turn
- Provides solution of complete problem
- Challenge: How to decompose so that good solutions are obtained?
- How to show optimality of solution?



Selecting Host boats

- Some additional side constraints
 - Some boats must be hosts
 - Some boats may not be hosts
- Reason on total or spare capacity
- No solution with 12 boats (with side constraints)



Solution to Phase 1

- Select boats 1 to 12 and 14 as hosts
- Many possible problem variants by selecting other host boats



Phase 2 Sub-problem

- Host boats and their capacity given
- Ignore host teams, only consider free capacity
- Assign guest teams to host boats



Model

- Assign guest boats to hosts for each time period
- Matrix (size NrGuests × NrPeriods) of domain variables x_{ii}
- Variables range over possible hosts 1..NrHosts



Constraints

- Each guest boat visits a host boat atmost once
- Two guest boats meet at most once
- All guest boats assigned to a host in a time period fit within spare capacity of host boat



Each guest visits a hosts atmost once

- The variables for a guest and different time periods must be pairwise different
- alldifferent constraint on rows of matrix
- all different $(\{x_{ij}|1 \le j \le NrPeriods\})$



Two guests meet at most once

- The variables for two guests can have the same value for atmost one time period
- Constraints on each pair of rows in matrix
- $x_{i_1j} = x_{i_2j}, i_1 \neq i_2 \Rightarrow x_{i_1k} \neq x_{i_2k} 1 \leq k \leq \text{NrPeriods}, k \neq j$



All guests assigned to a host in a time period fit within spare capacity of host boat

- Capacity constraint expressed as bin packing for each time period
- Each host boat is a bin with capacity from 0 to its unused capacity
- Each guest is an item to be assigned to a bin
- Size of item given by crew size of guest boat





Bin Packing Constraint

- Global constraint
 bin_packing (Assignment, Sizes, Capacity)
- Items of different sizes are assigned to bins
- Assignment of item modelled with domain variable (first argument)
- Size of items fixed: integer values (second argument)
- Each bin may have a different capacity
- Capacity of each bin given as a domain variable (third argument)



Outline

- Problem
- 2 Program
- 3 Search
- A Further Decomposition



Main Program

```
top:-
    top(10,6).

top(Problem, Size):-
    problem(Problem, Hosts, Guests),
    model(Hosts, Guests, Size, Matrix),
    writeln(Matrix).
```



Data

```
problem(10,

[10,10,9,8,8,8,8,8,8,7,6,6,4],

[7,6,5,5,5,4,4,4,4,4,4,4,4,4,3,

3,2,2,2,2,2,2,2,2,2,2,2,2,2]).
```



Creating Variables

```
model(Hosts, Guests, NrPeriods, Matrix):-
    length(Hosts, NrHosts),
    length(Guests, NrGuests),
    dim(Matrix, [NrGuests, NrPeriods]),
    Matrix[1..NrGuests, 1..NrPeriods] :: 1..NrHosts,
    ...
```



Setting up alldifferent constraints

```
(for(I,1,NrGuests),
  param(Matrix,NrPeriods) do
    ic:alldifferent(Matrix[I,1..NrPeriods])
),
```



Setting up bin_packing constraints



Each pair of guests meet atmost once

Call search

```
extract_array(col,Matrix,List),
assign(List).
```



Make Bin variables

```
make_bins(HostCapacity,Bins):-
    (foreach(Cap,HostCapacity),
        foreach(B,Bins) do
        B:: 0..Cap
).
```



Each pair of guests meet atmost once

```
card_leq(Vector1, Vector2, Card):-
    collection_to_list(Vector1, List1),
    collection_to_list(Vector2, List2),
    (foreach(X, List1),
     foreach(Y, List2),
     fromto(0, A, A+B, Term) do
        #=(X, Y, B)
    ),
    eval(Term) #=< Card.</pre>
```



Naive Search



Outline

- 1 Problem
- 2 Program
- Search
 - First Fail Strategy
 - Layered Search
 - Layered with Credit Search
 - Randomized with Restart
 - A Further Decomposition



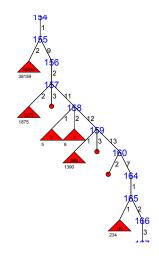


Naive Search (Compact view)





Naive Search (Zoomed)







Observations

- Not too many wrong choices
- But very deep backtracking required to discover failure
- Most effort wasted in "dead" parts of search tree



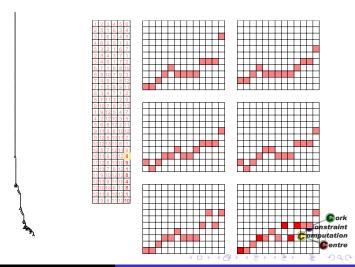
First Fail Strategy Layered Search Layered with Credit Search Randomized with Restart

First Fail strategy



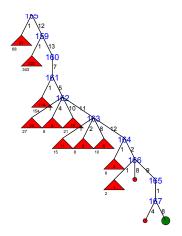
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First Fail Search



First Fail Strategy Layered Search Layered with Credit Search Randomized with Restart

First Fail Search (Zoomed)





Observations

- Assignment not done in row or column mode
- Tree consists of straight parts without backtracking
- ... and nearly fully explored parts



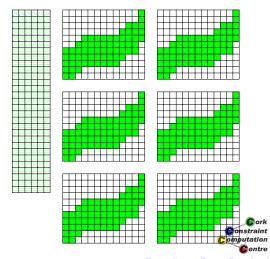
Idea

- Assign variables by time period
- Within one time period, use first_fail selection
- Solves bin packing packing for each period completely
- Clearer impact of disequality constraints
- Serial composition of search procedures

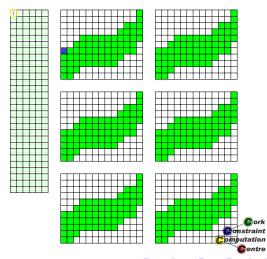




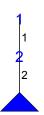


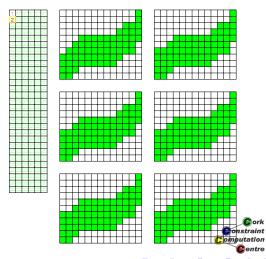




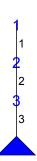


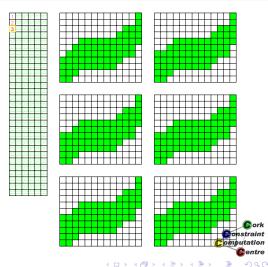






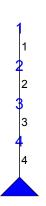


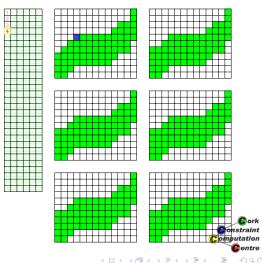




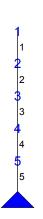


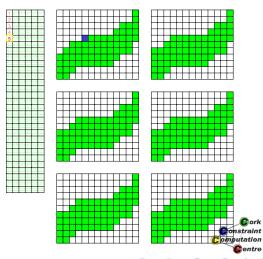
Customizing Search



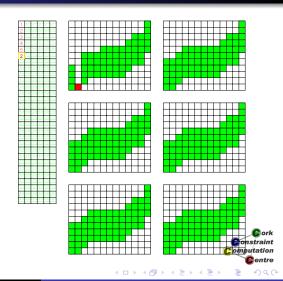




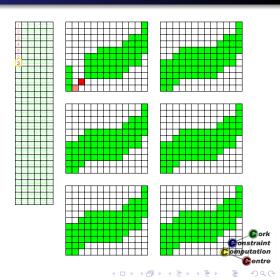




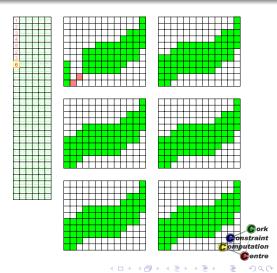




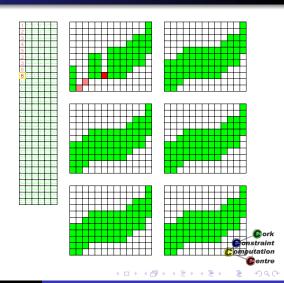




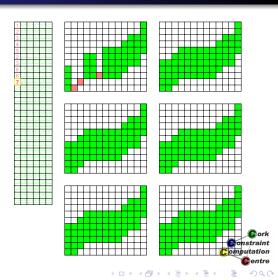






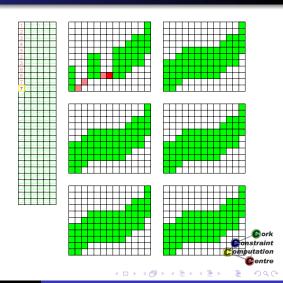




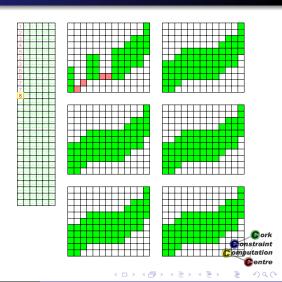






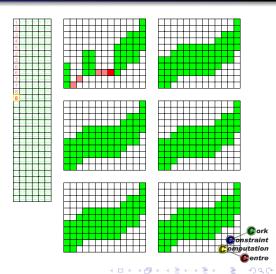




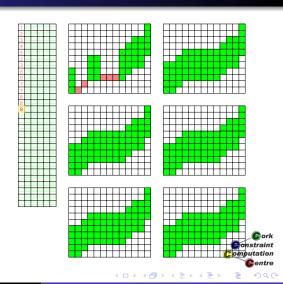


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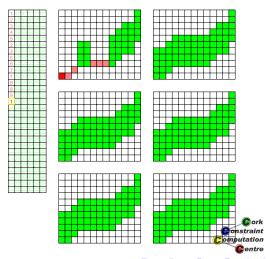




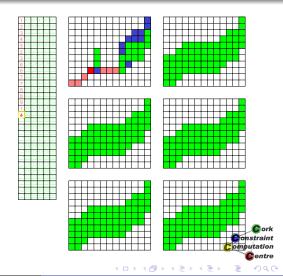




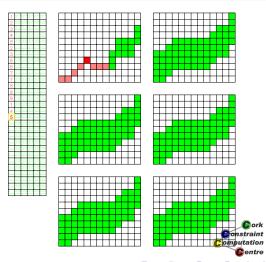




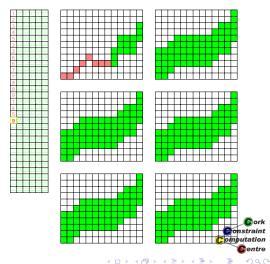






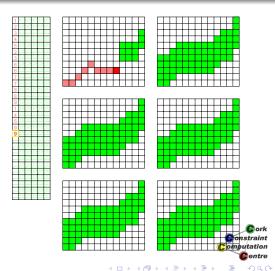






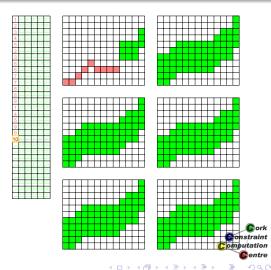






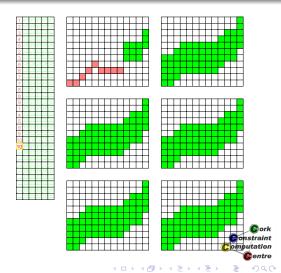




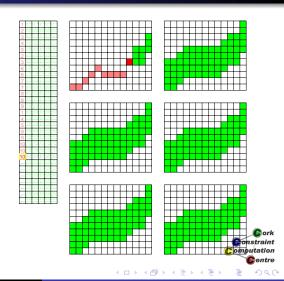


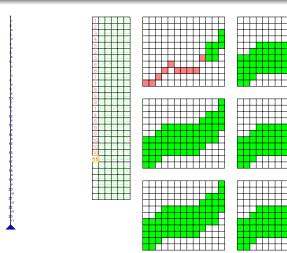






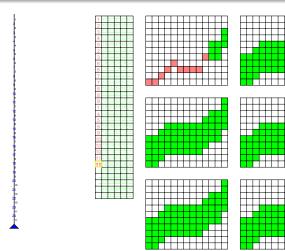








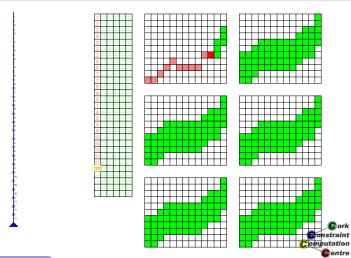
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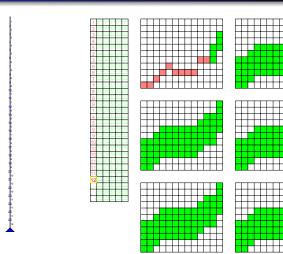






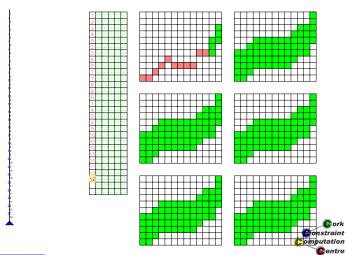
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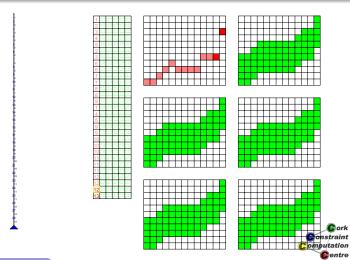


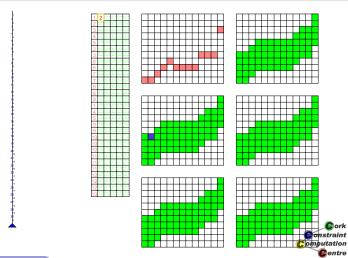




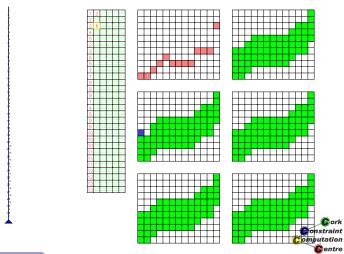
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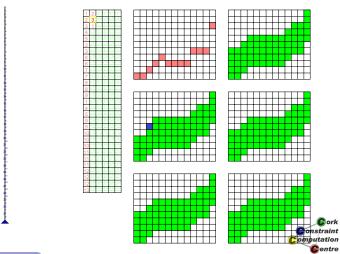


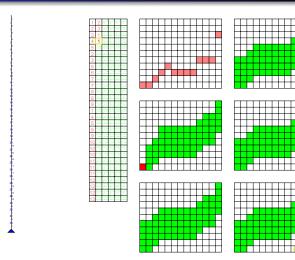




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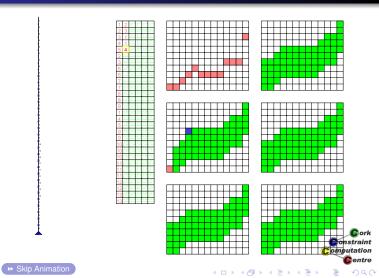




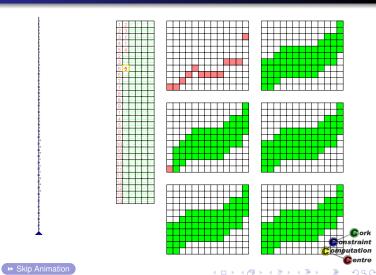
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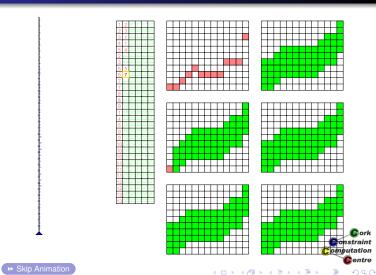
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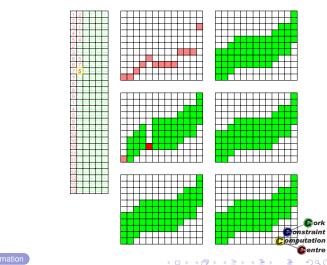


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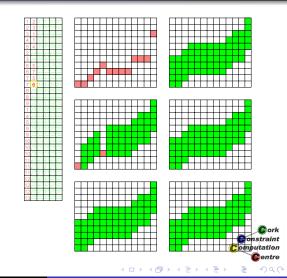
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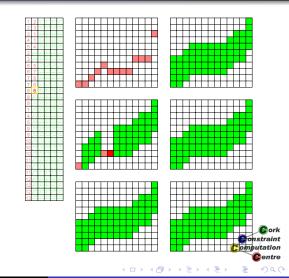


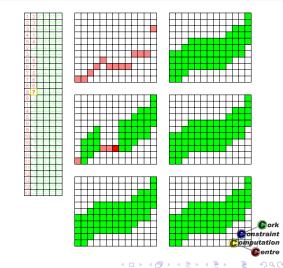


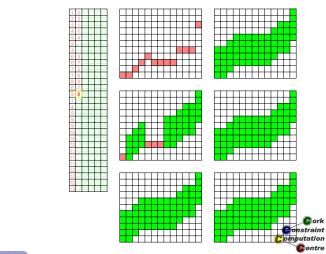
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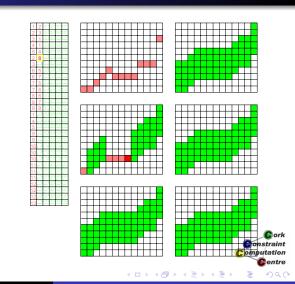


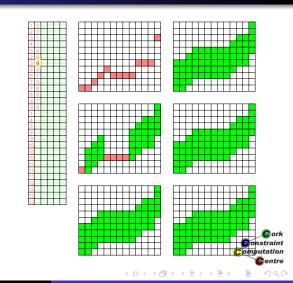


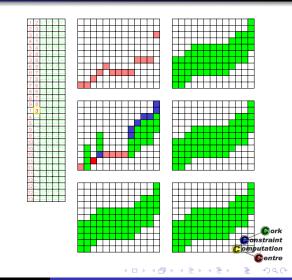


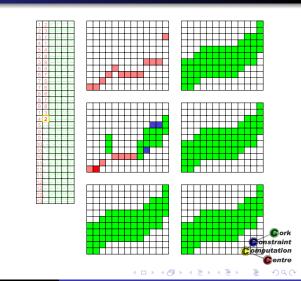


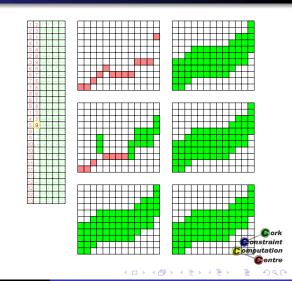
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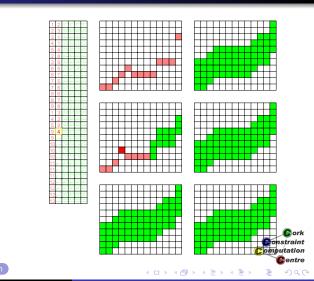


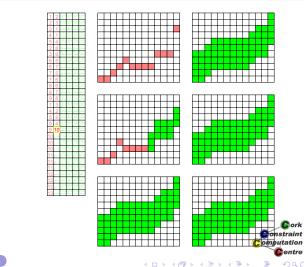


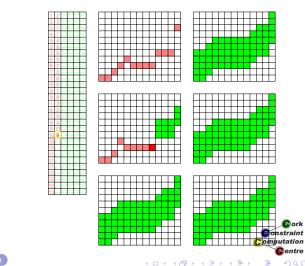


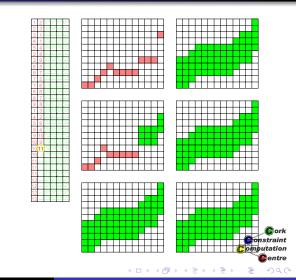


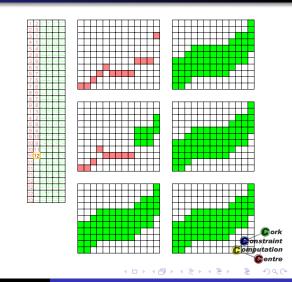




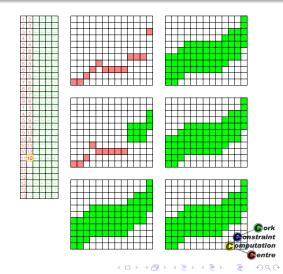




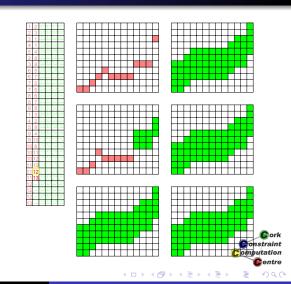


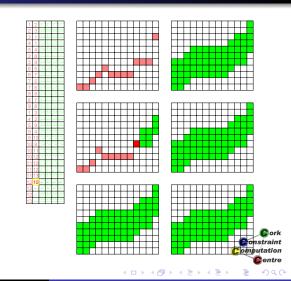


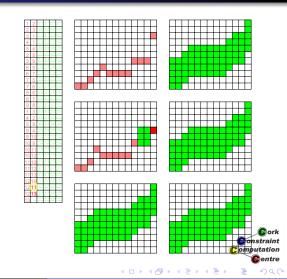
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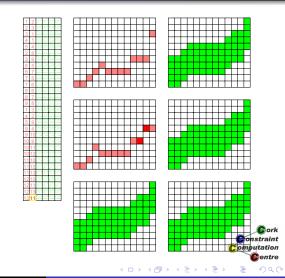


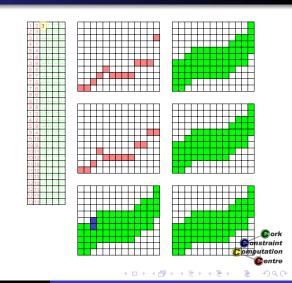
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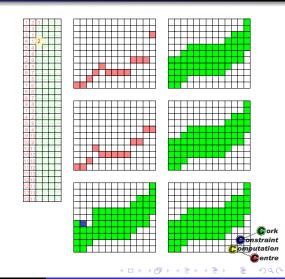


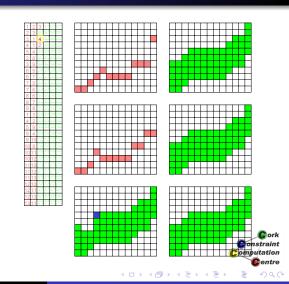


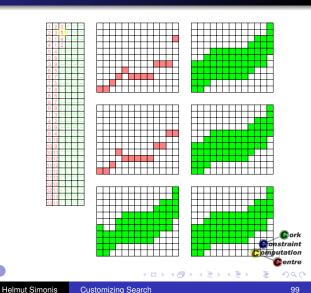


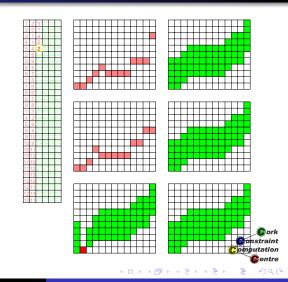


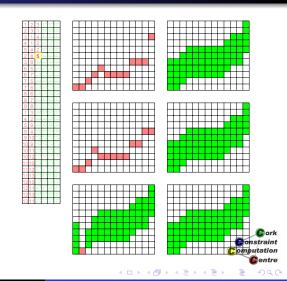


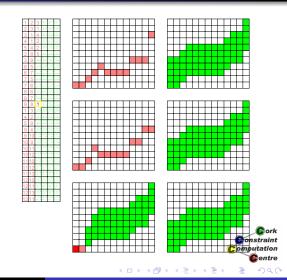


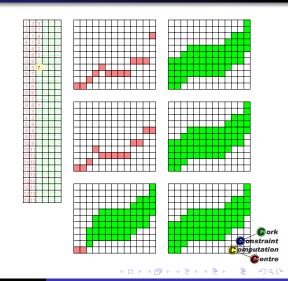


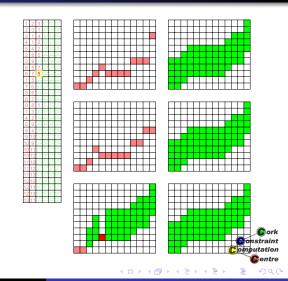


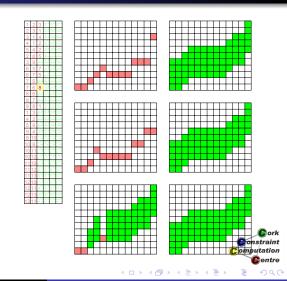


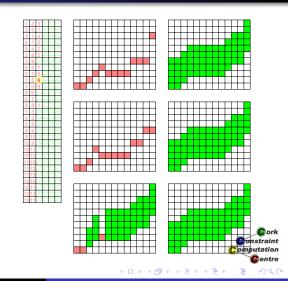


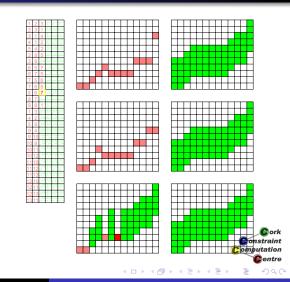


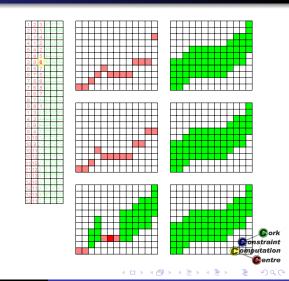




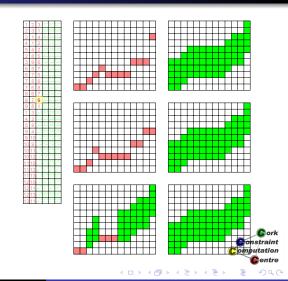


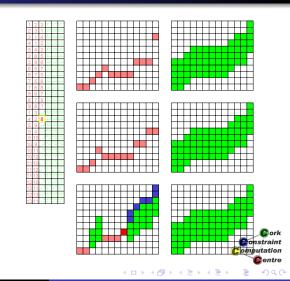


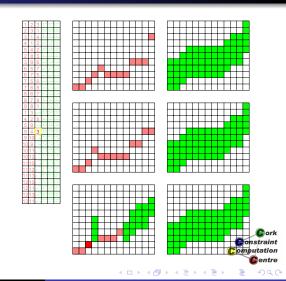


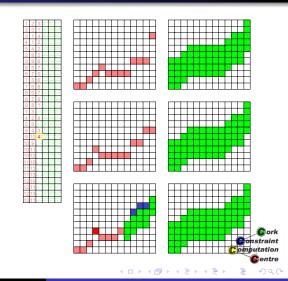


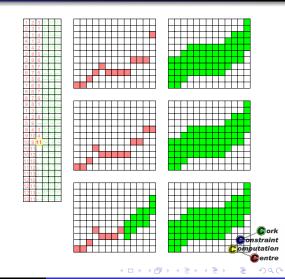


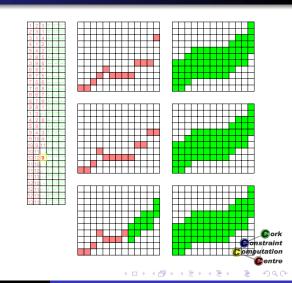


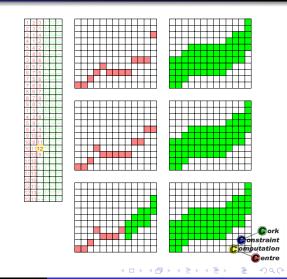


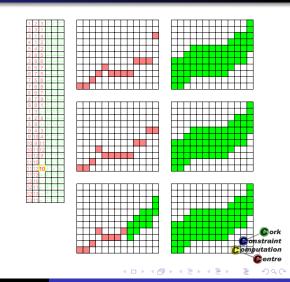


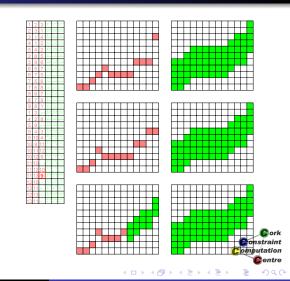


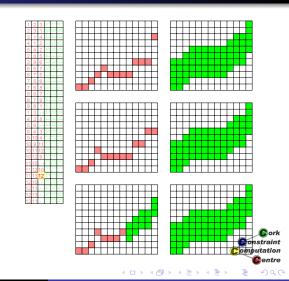


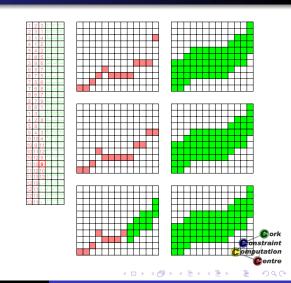




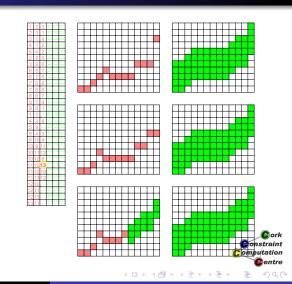


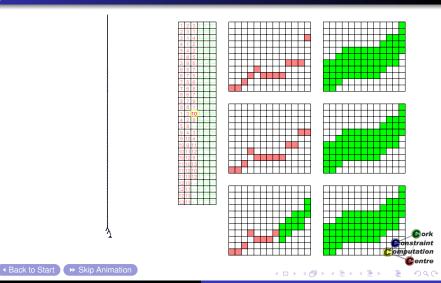


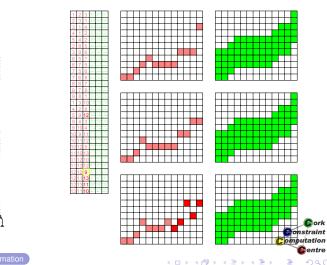


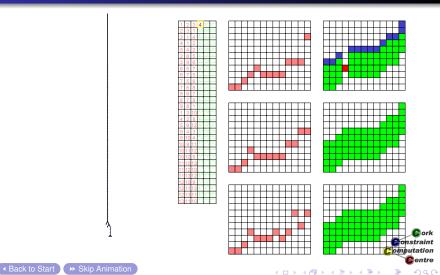


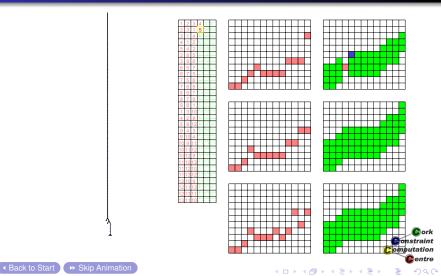


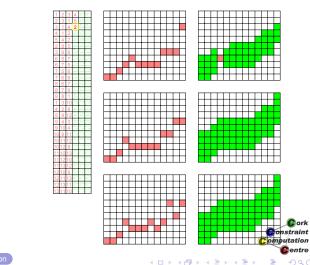


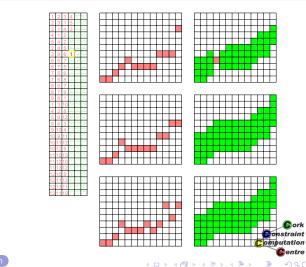


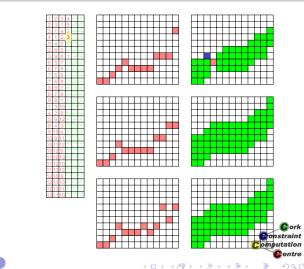


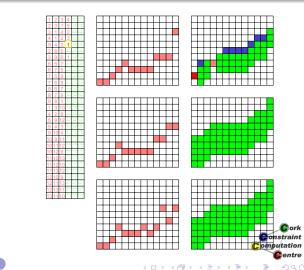


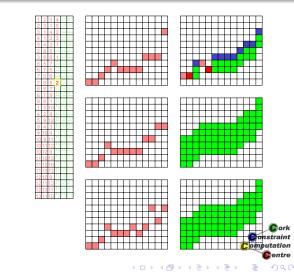






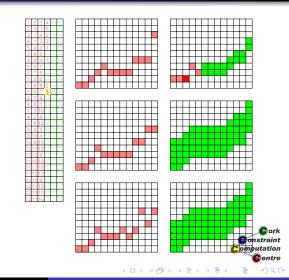






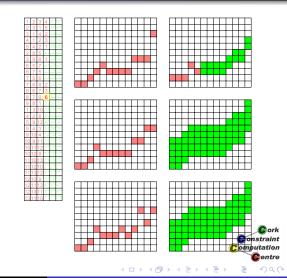
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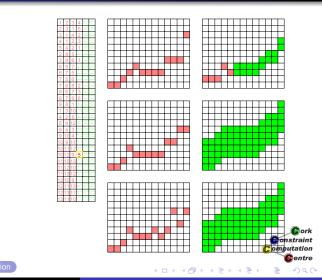
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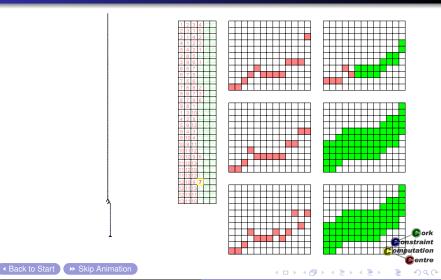


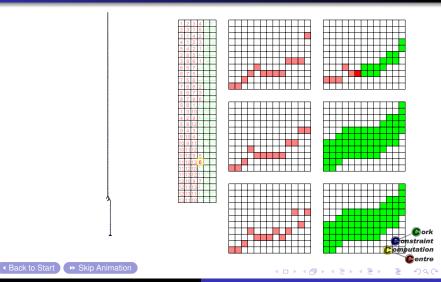
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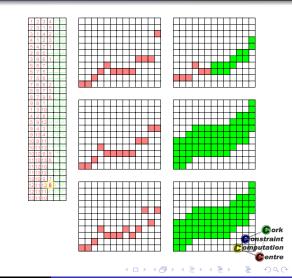


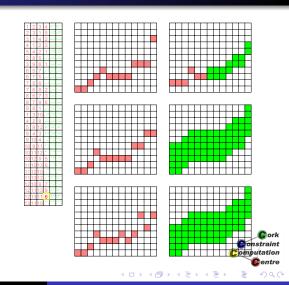


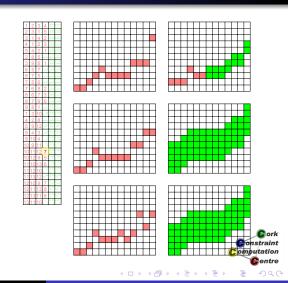


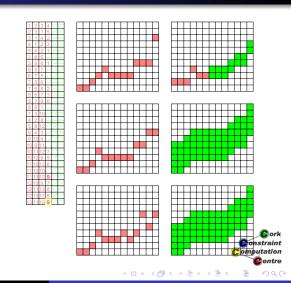
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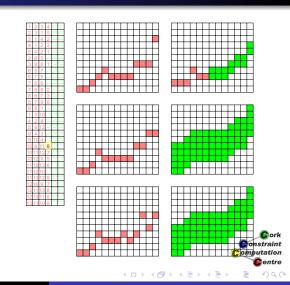
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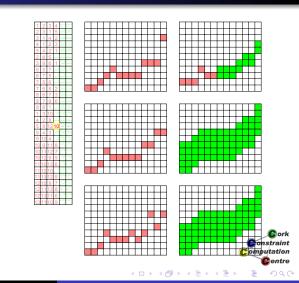


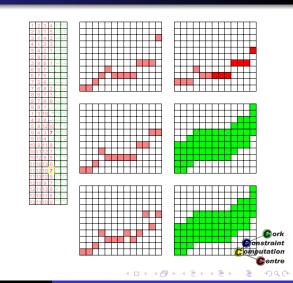


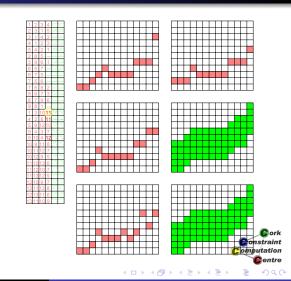




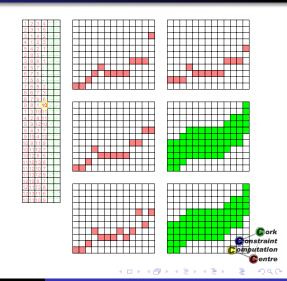


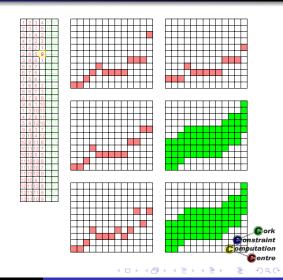


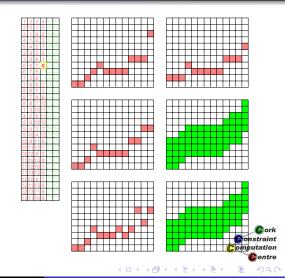


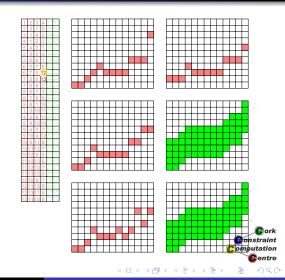


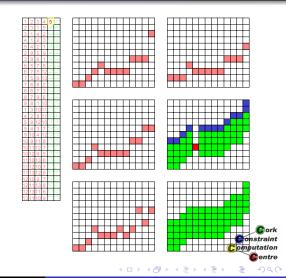


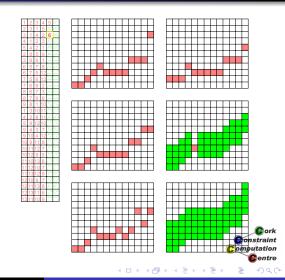


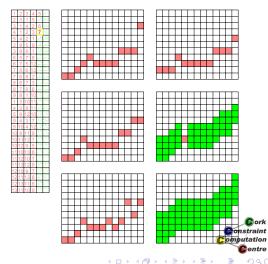


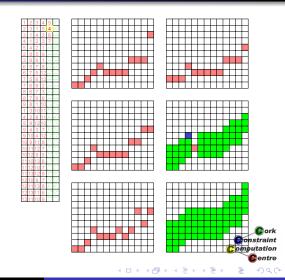


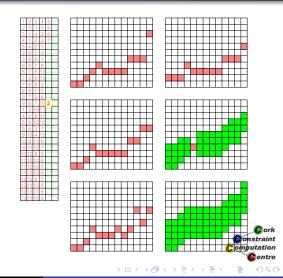


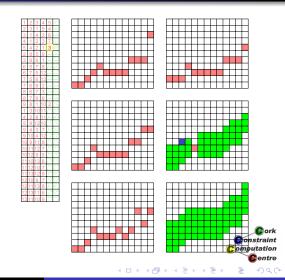


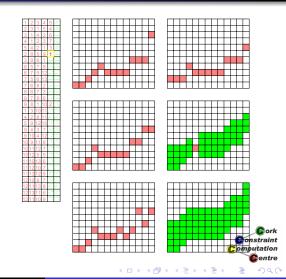


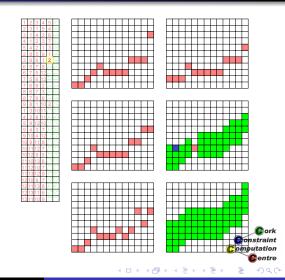


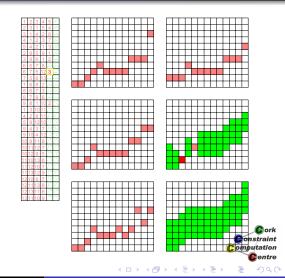


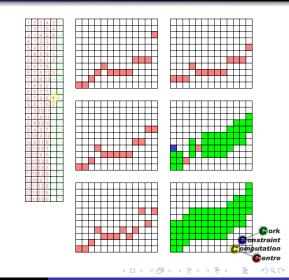


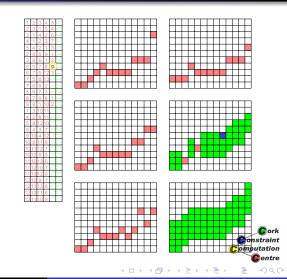


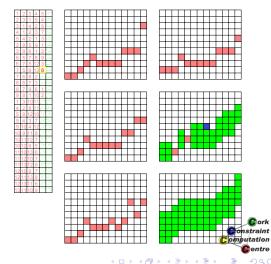


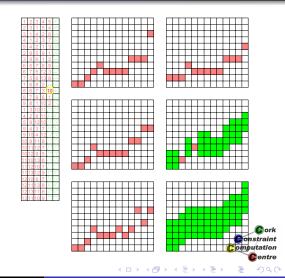


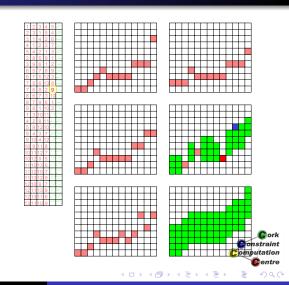




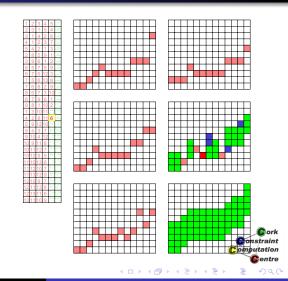


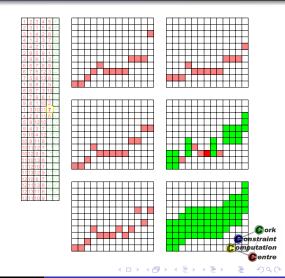


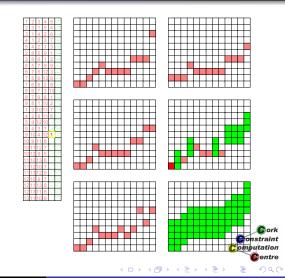




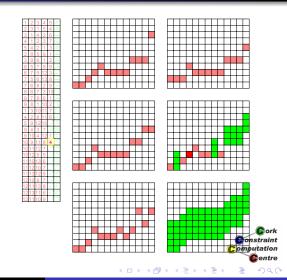


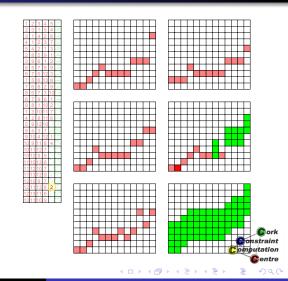




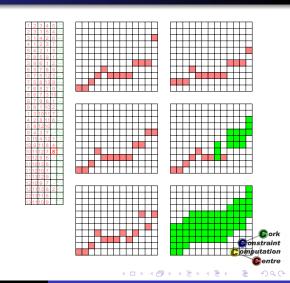




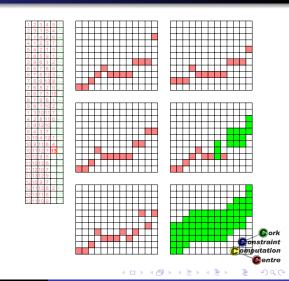


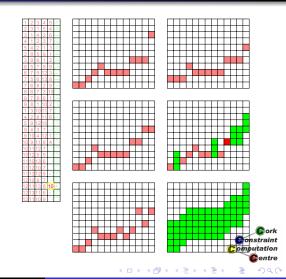


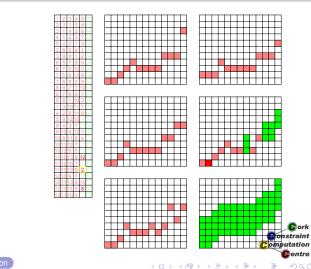


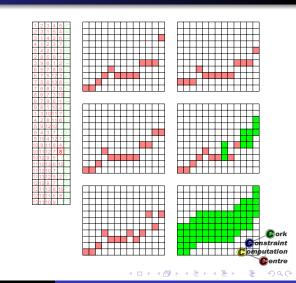


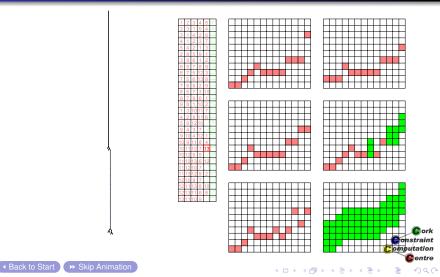


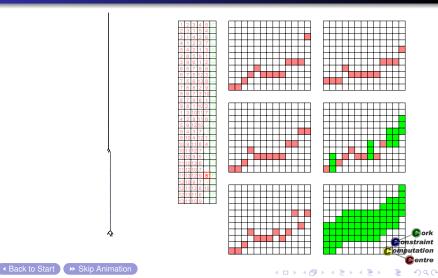


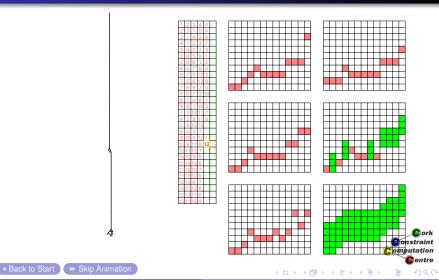


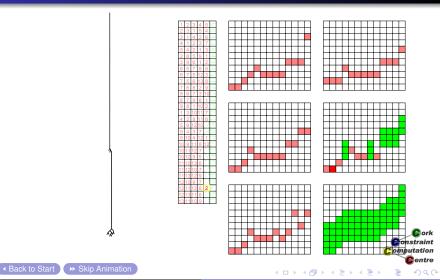


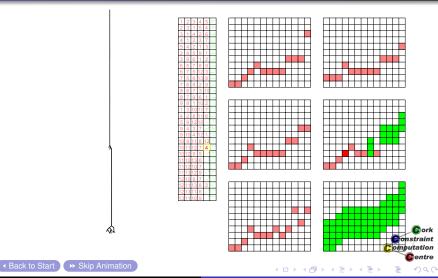


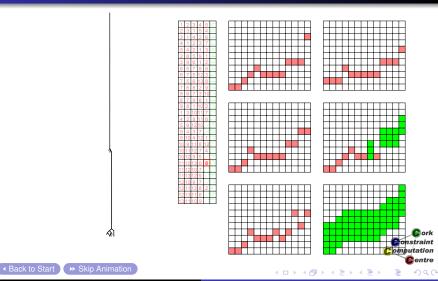


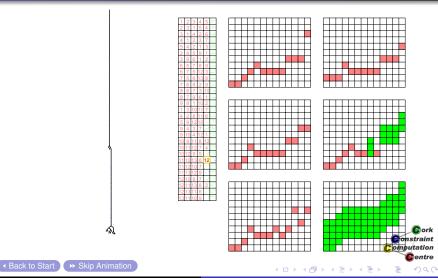


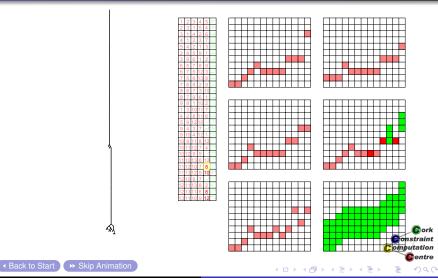


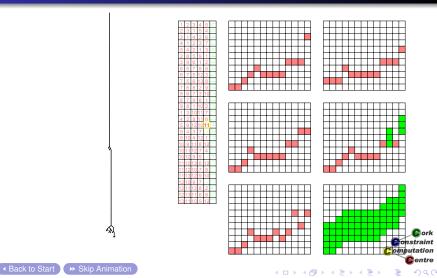


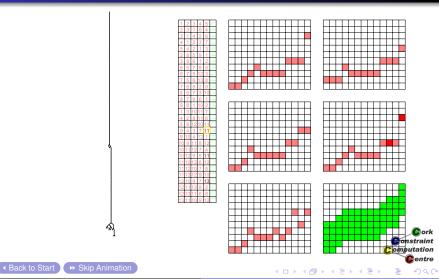


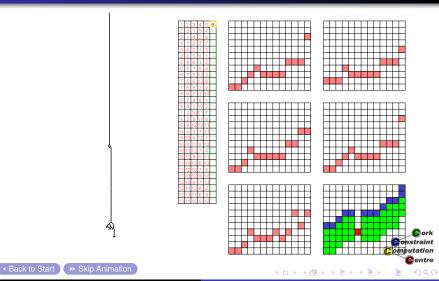


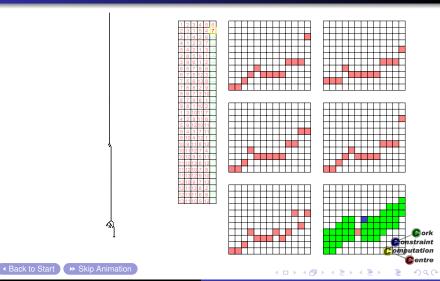


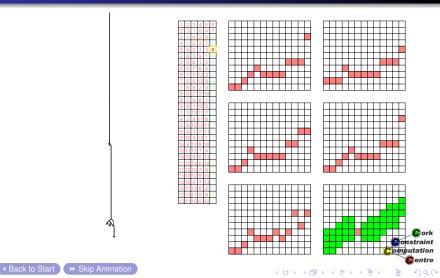


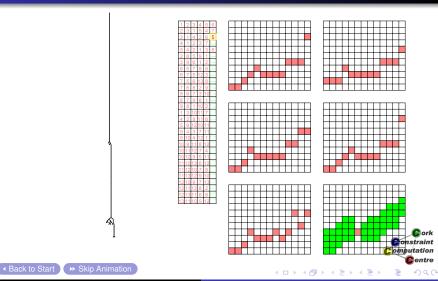


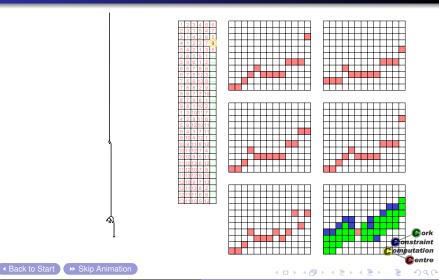


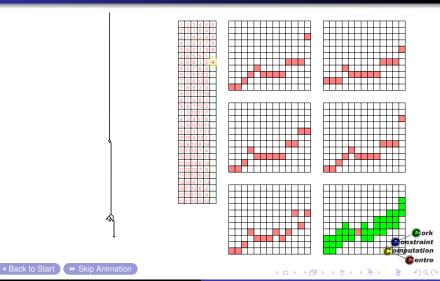


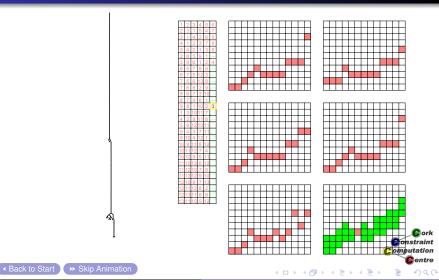


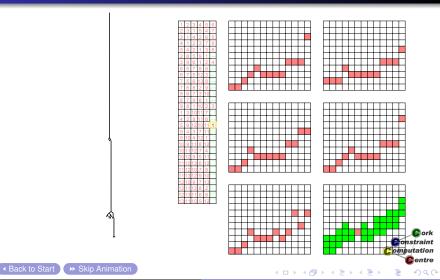


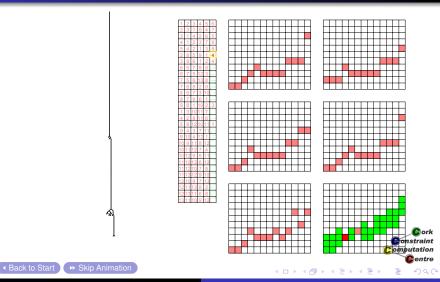


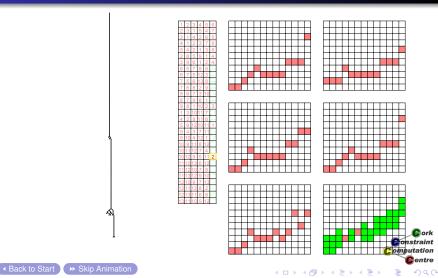


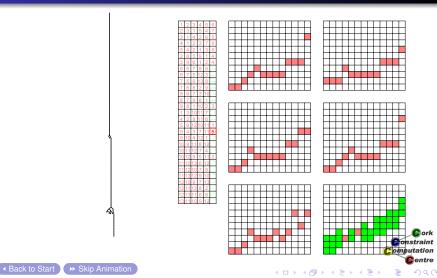


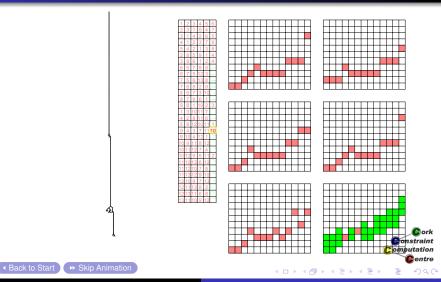


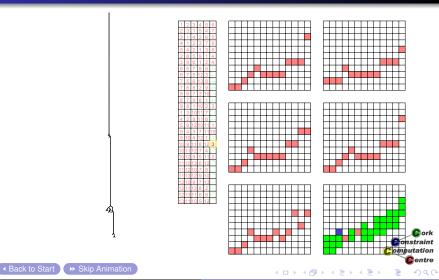


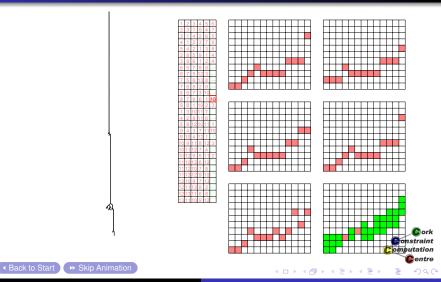


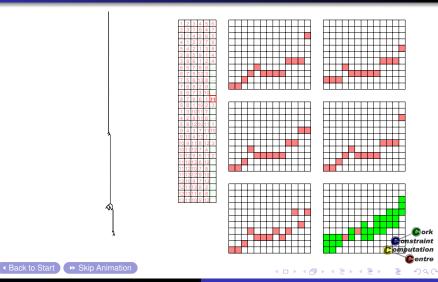


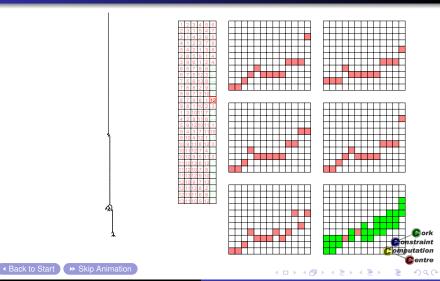


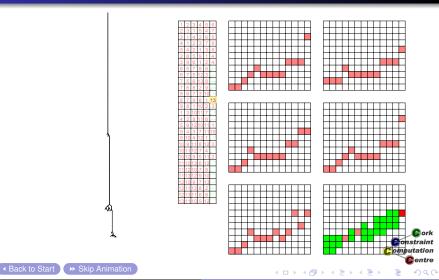


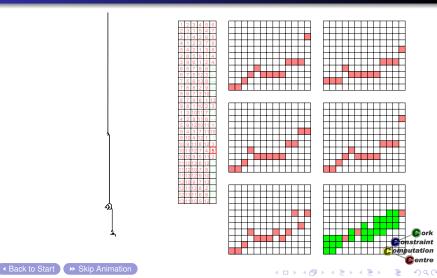


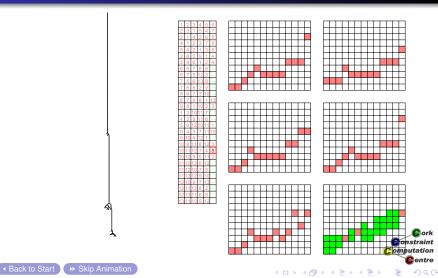


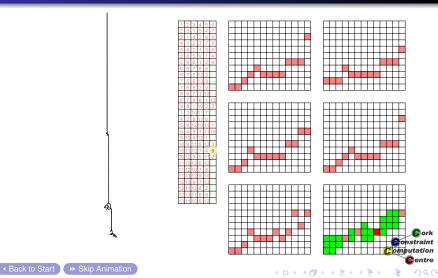


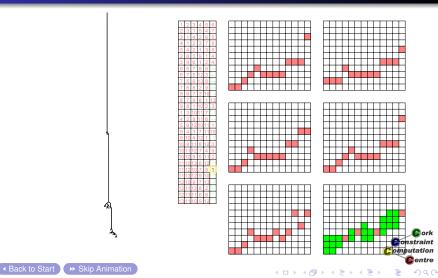


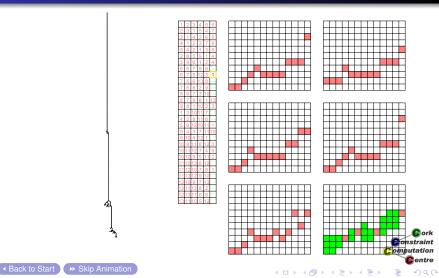


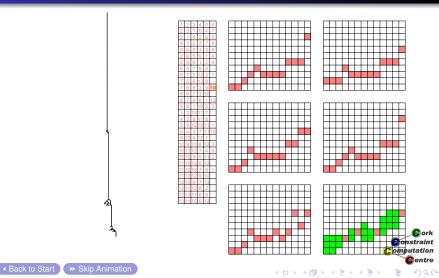


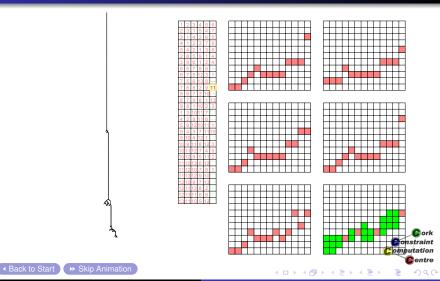


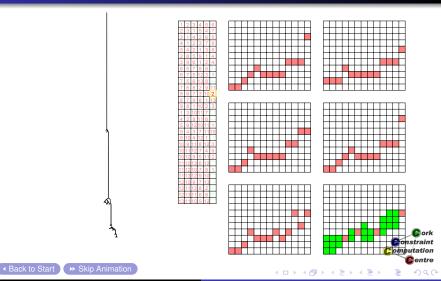


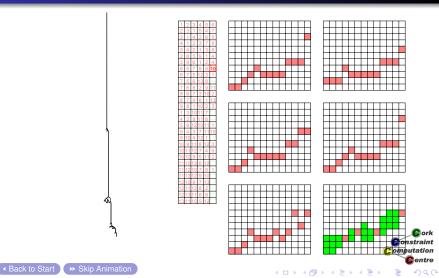


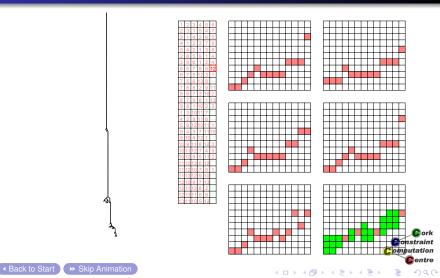


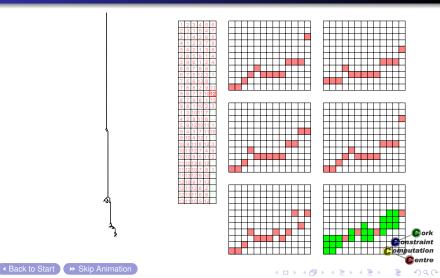


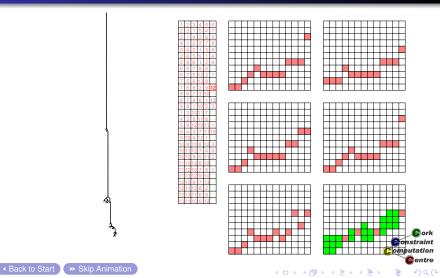


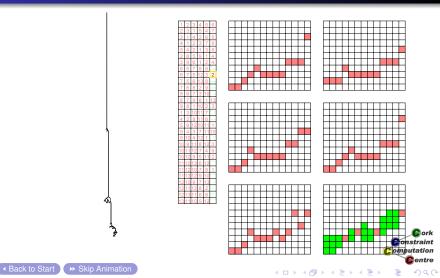


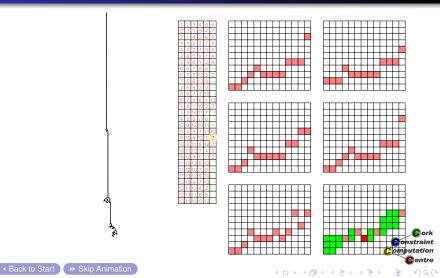


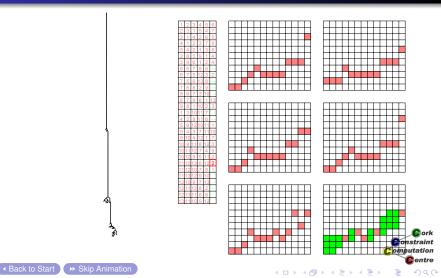


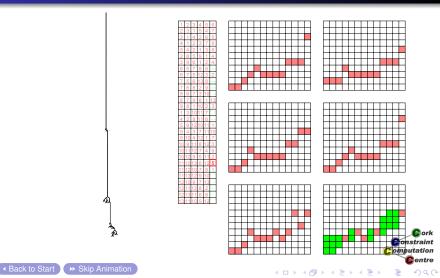


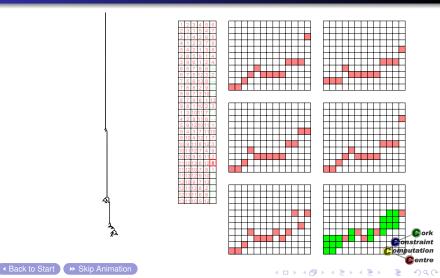


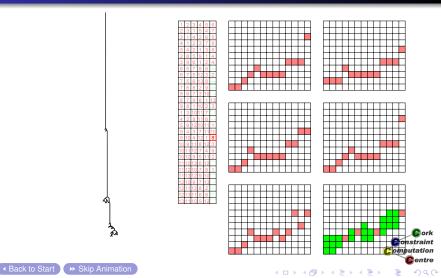


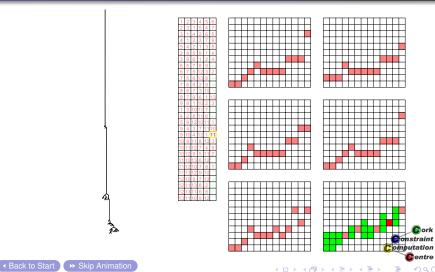


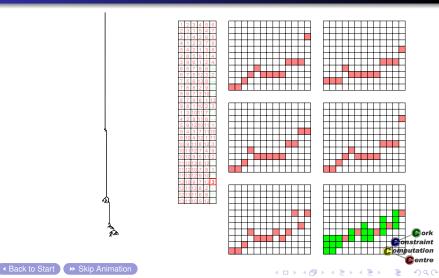


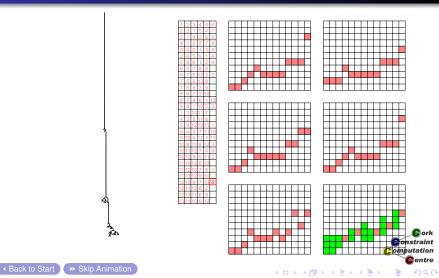


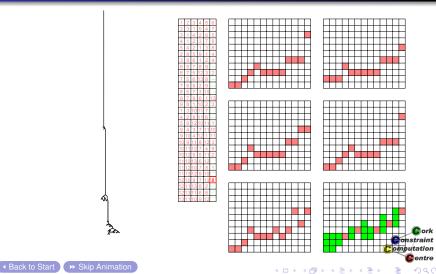


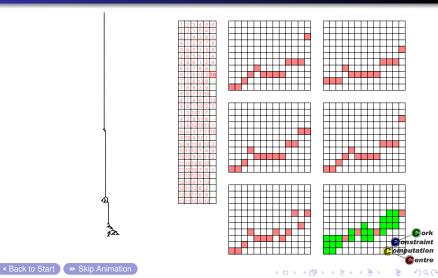


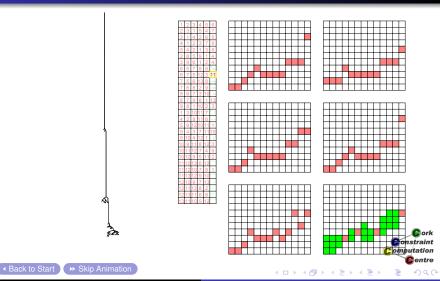


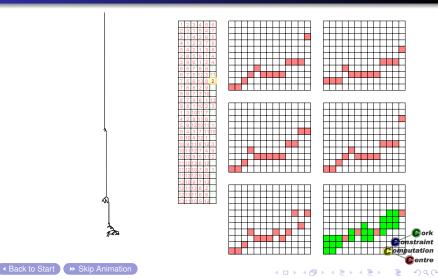


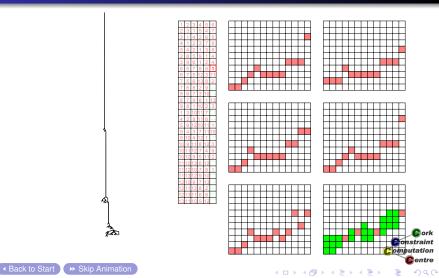


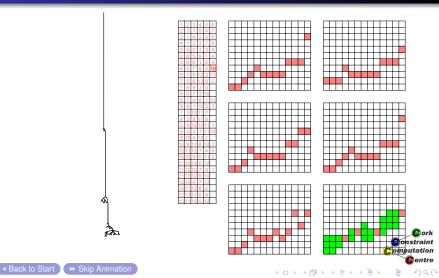


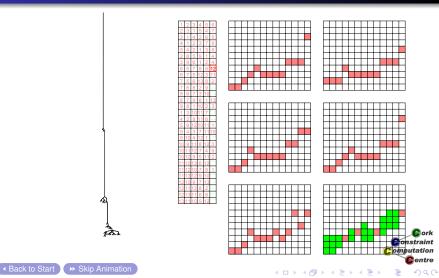


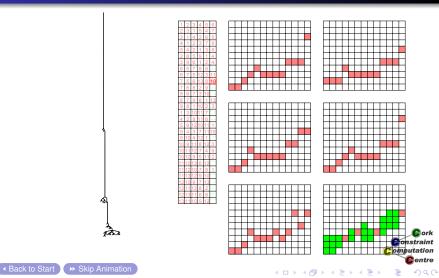


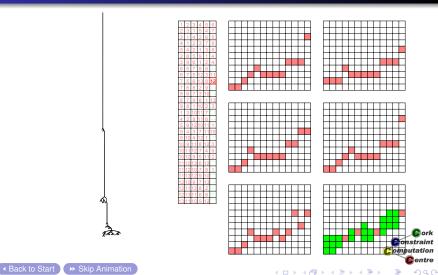


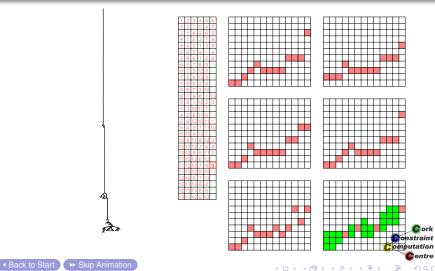


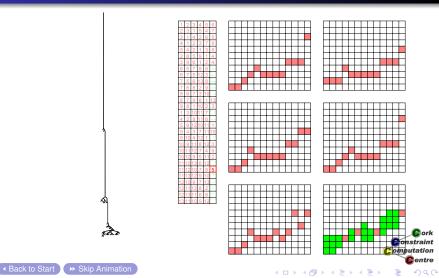


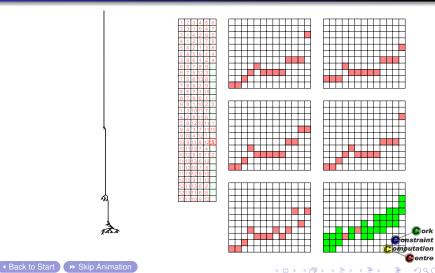


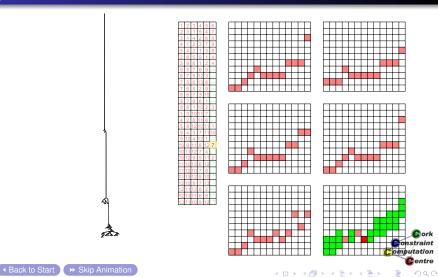


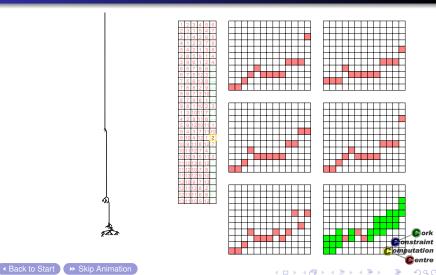


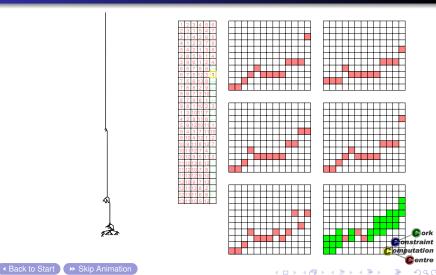


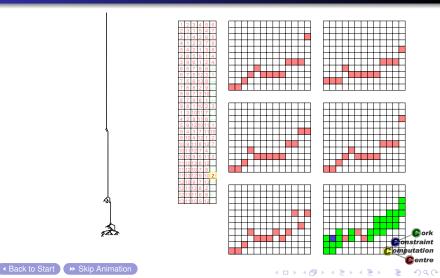


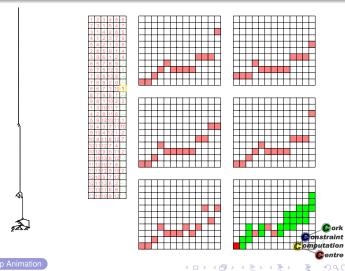


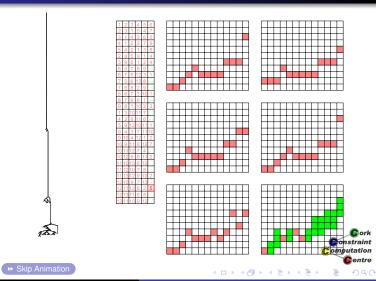


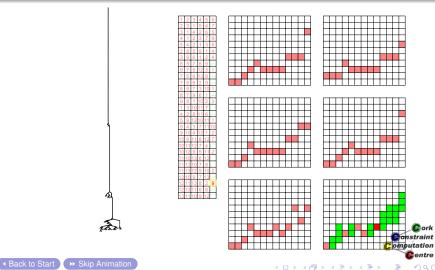


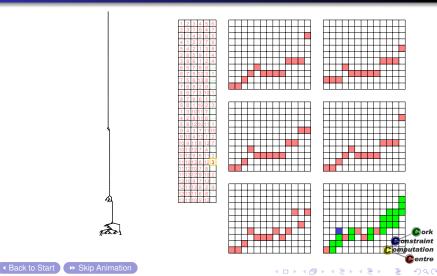


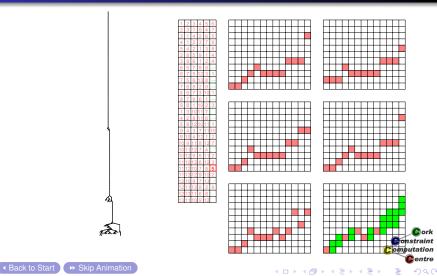


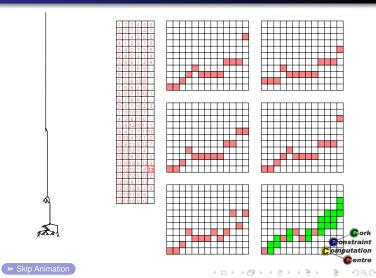


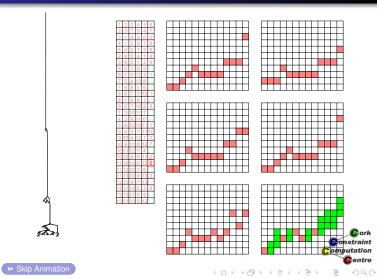


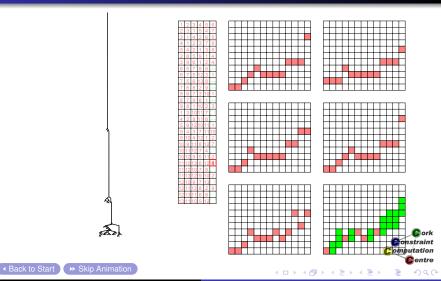


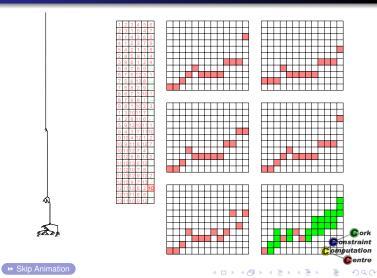


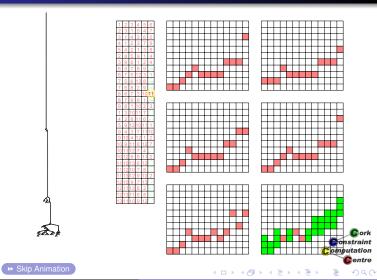


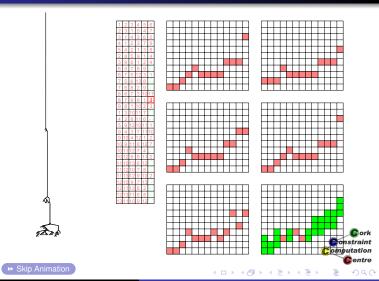


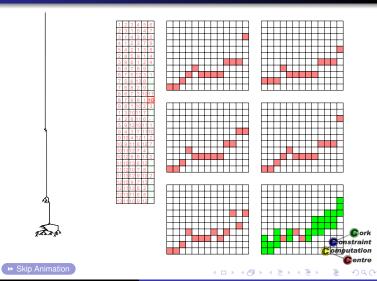


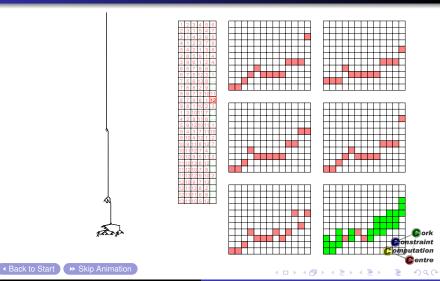


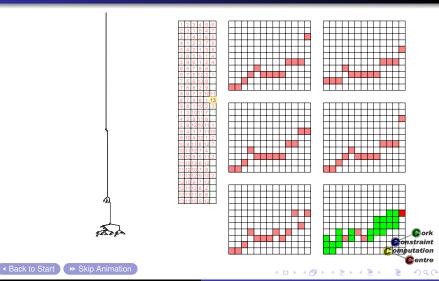


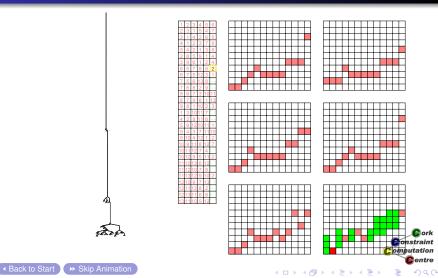


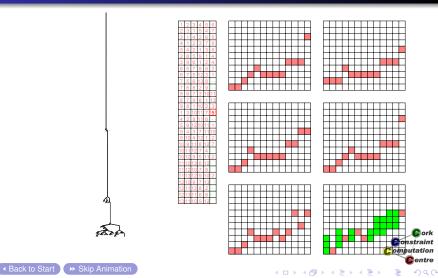


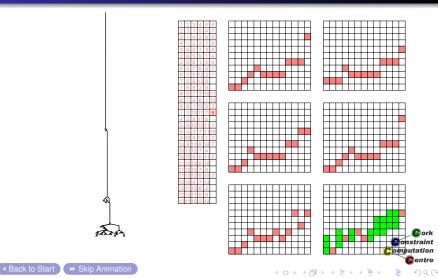


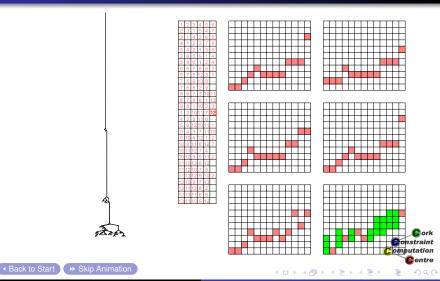


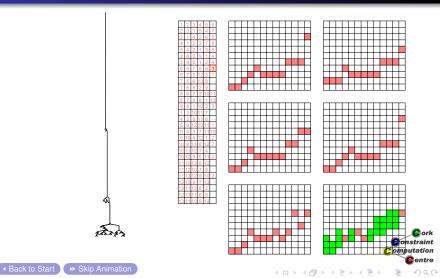


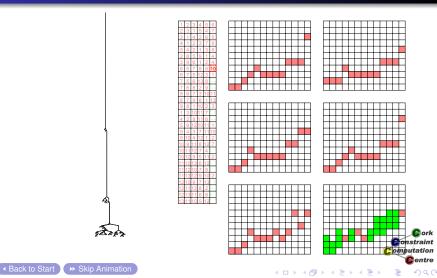


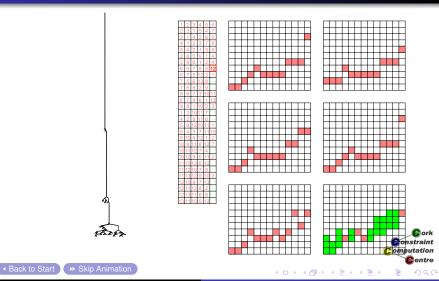


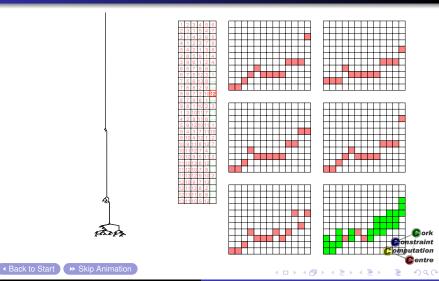


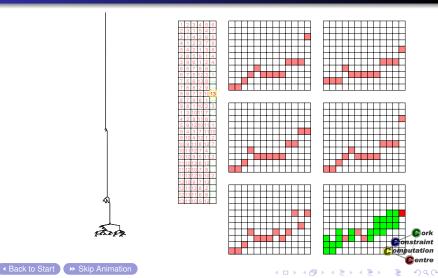


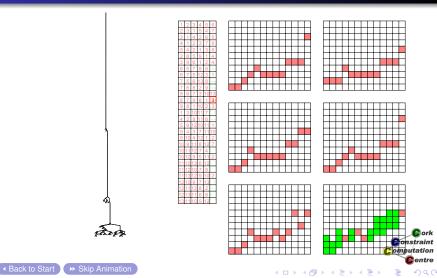


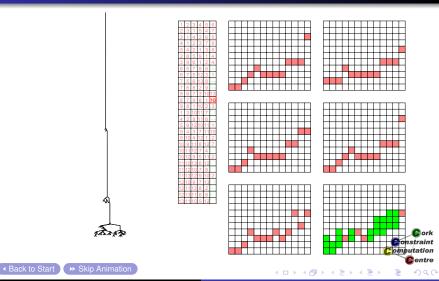


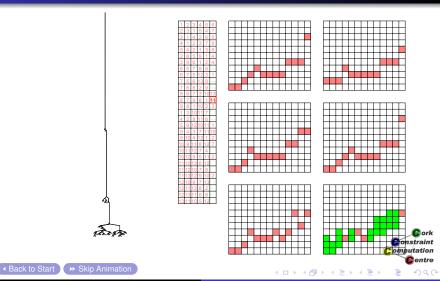


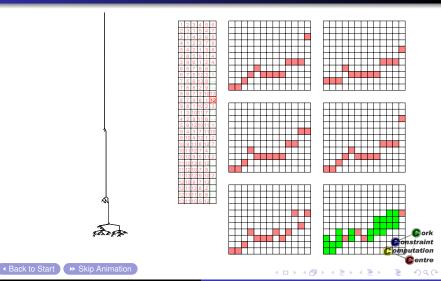


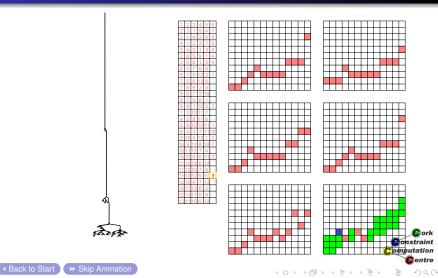


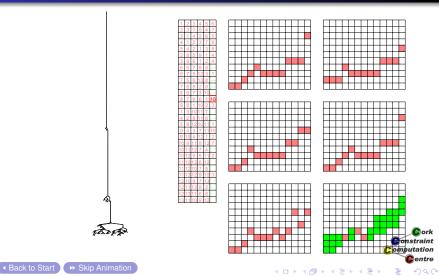


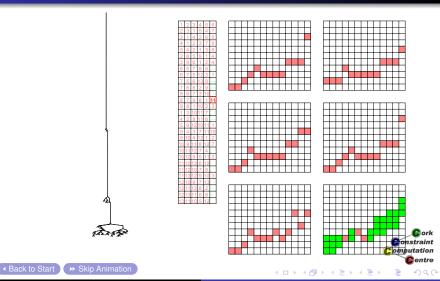


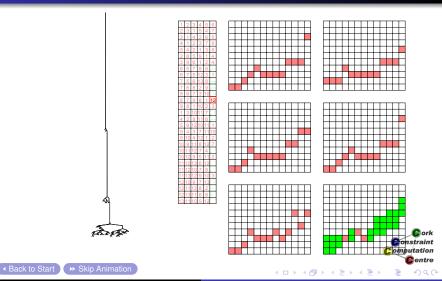


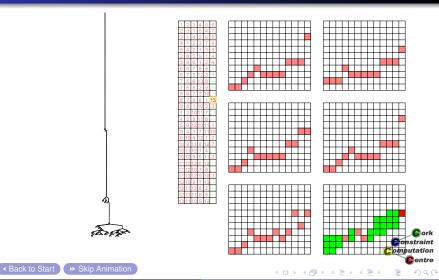


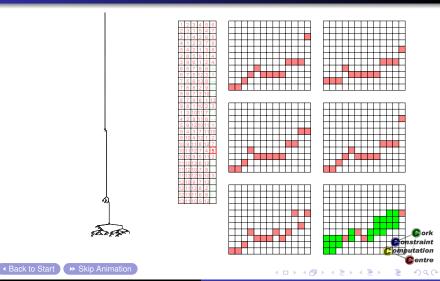


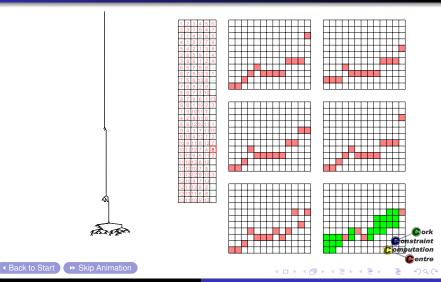


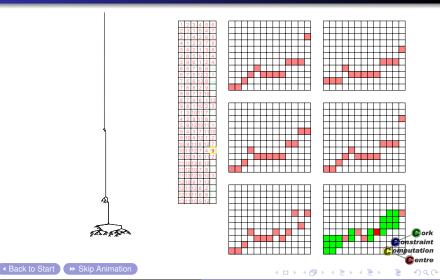


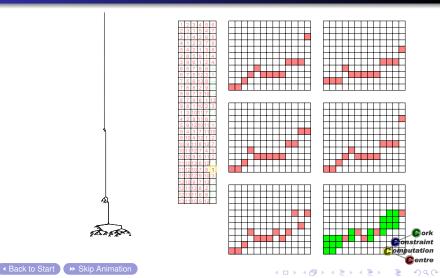


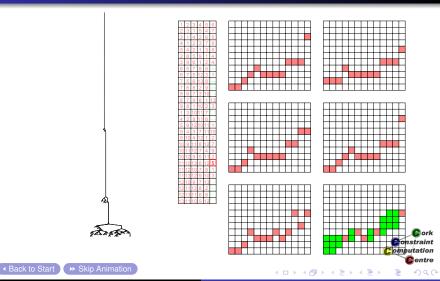


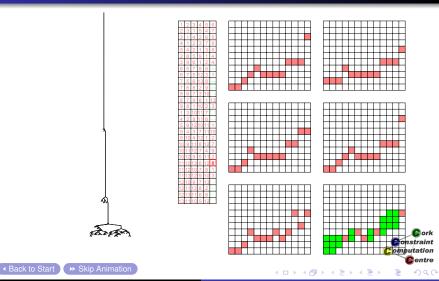


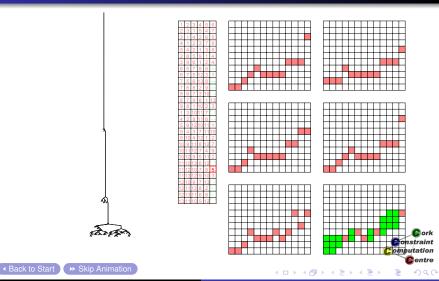


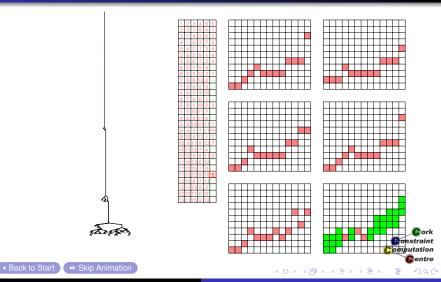


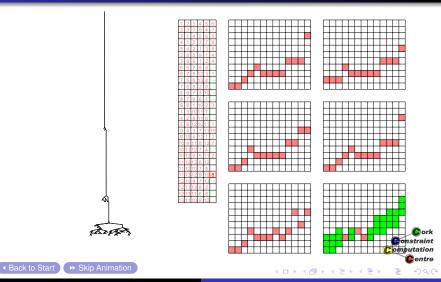


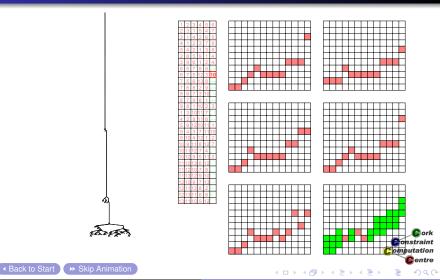


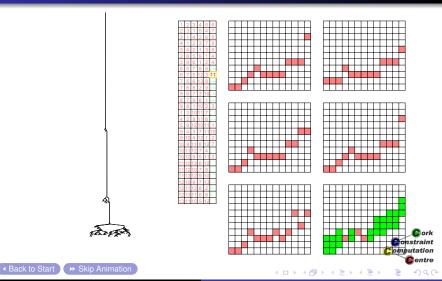


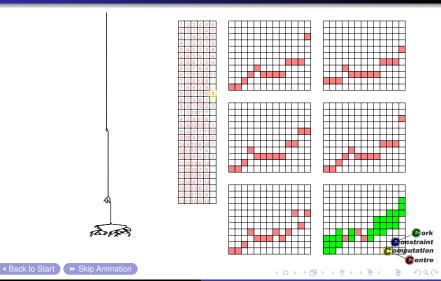


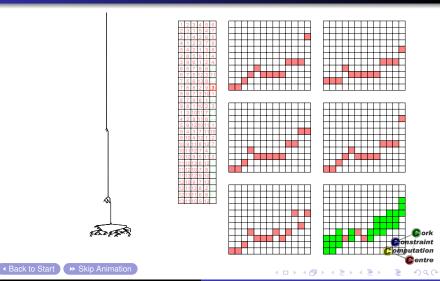


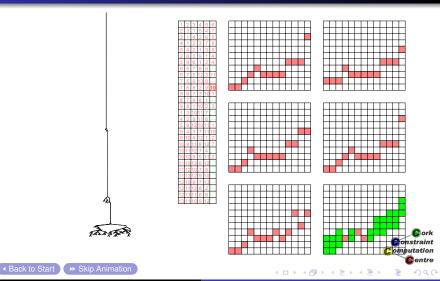


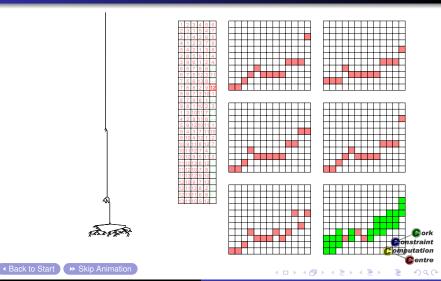


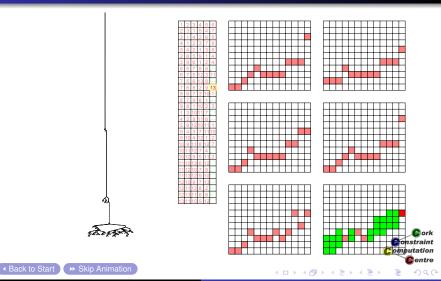


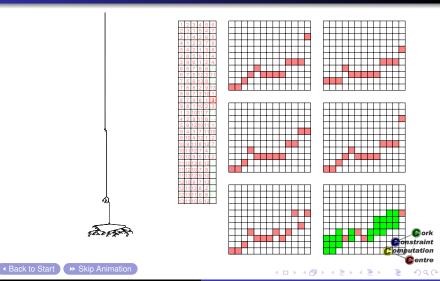


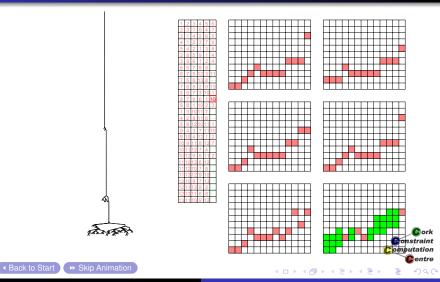


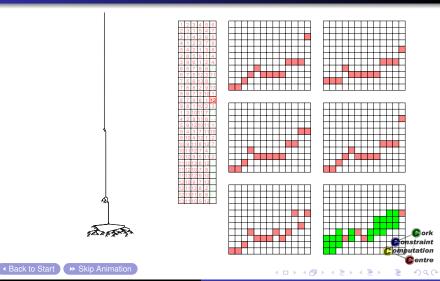


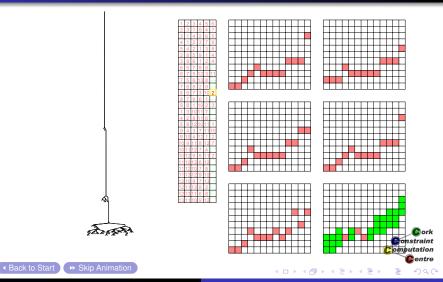


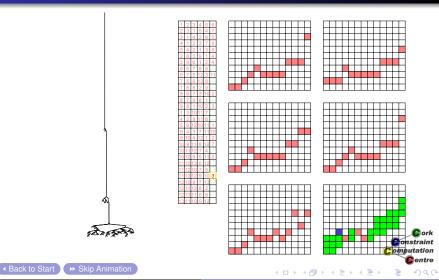


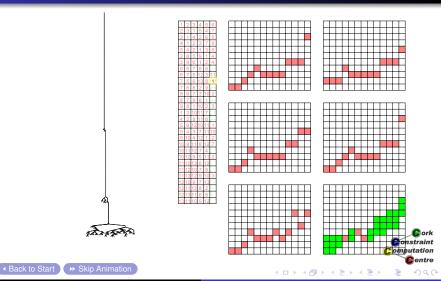


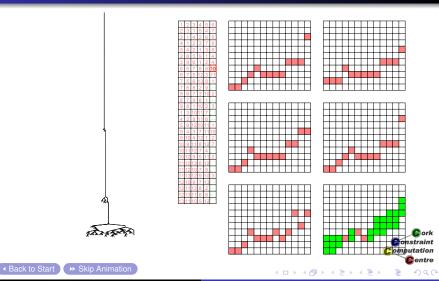


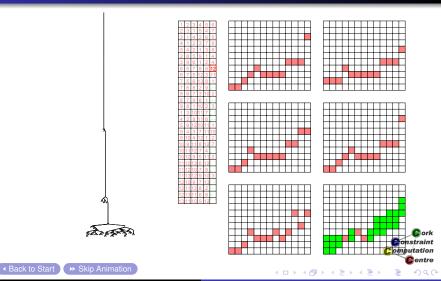


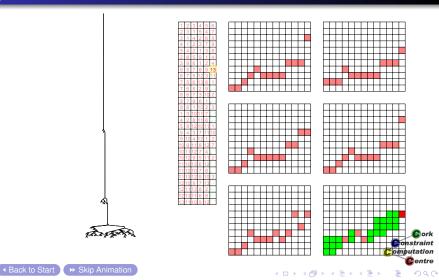


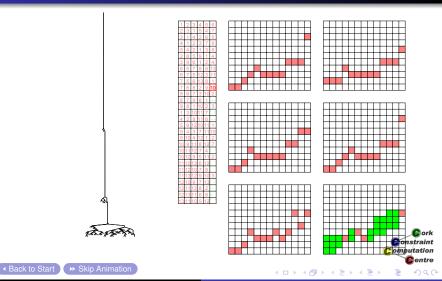


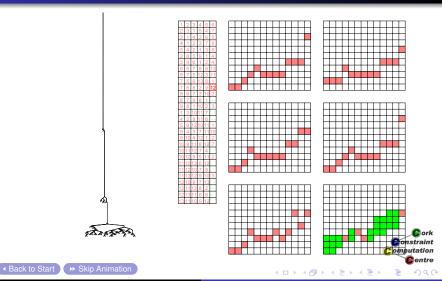


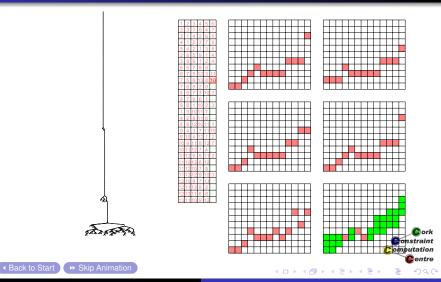


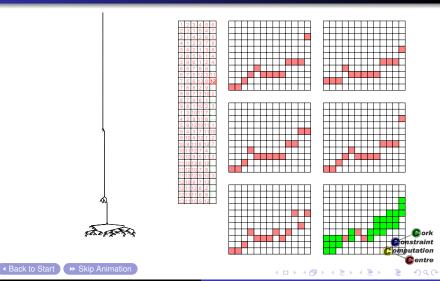


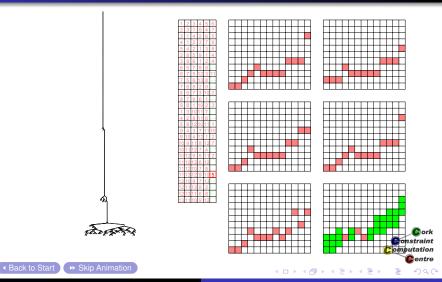


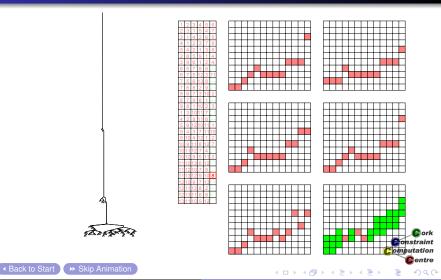


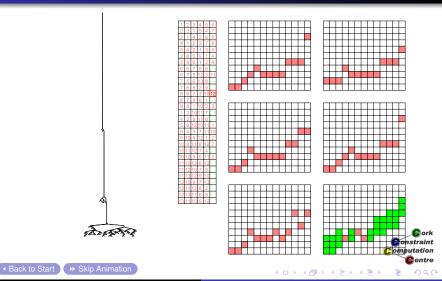


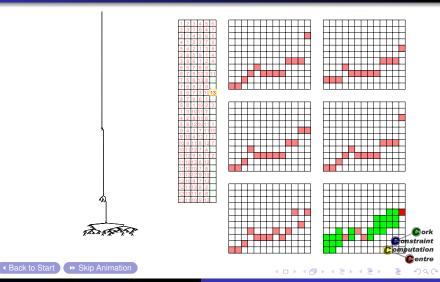


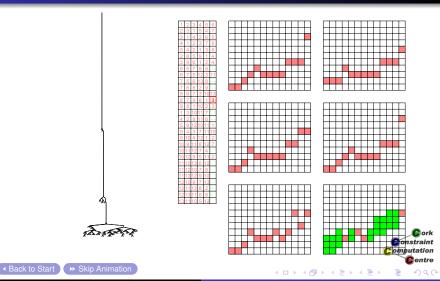


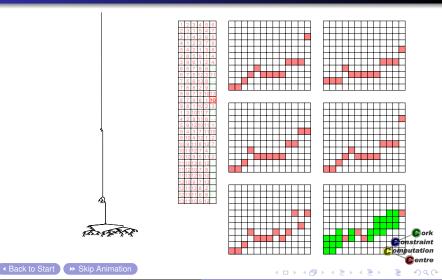


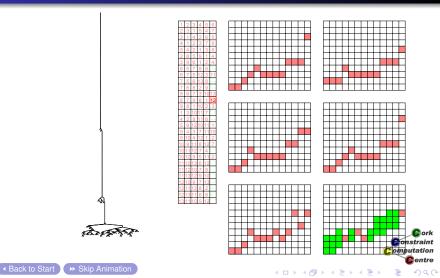


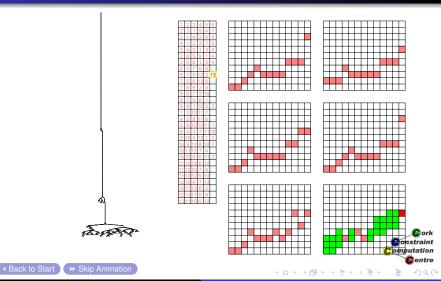


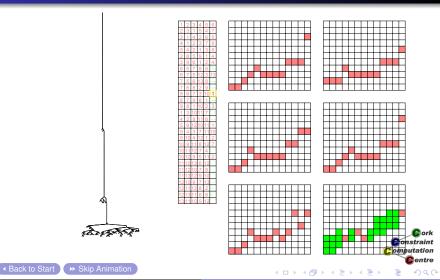


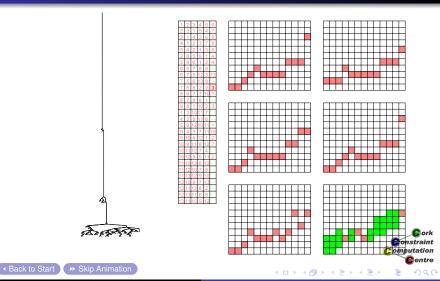


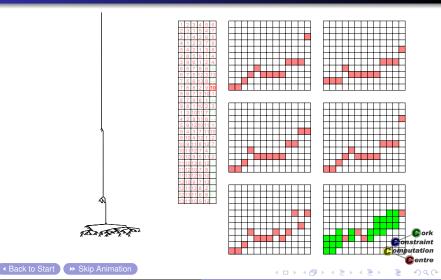


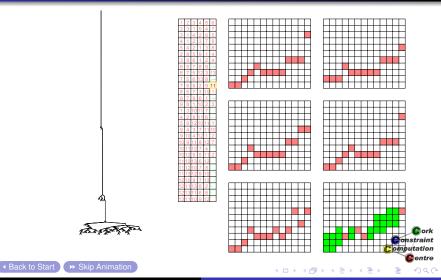


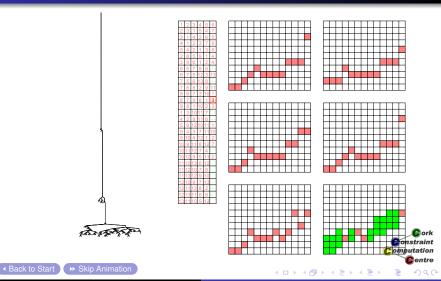


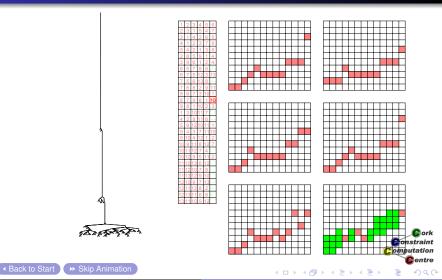


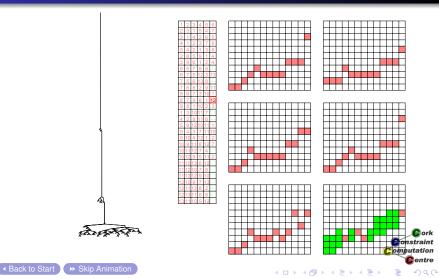


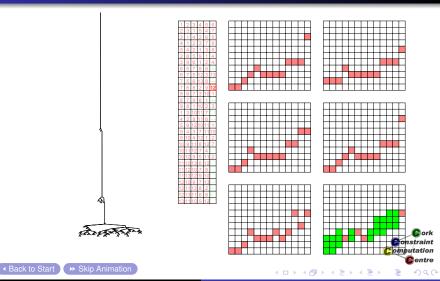


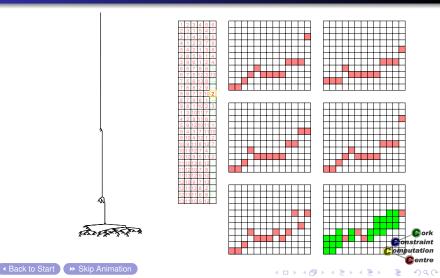


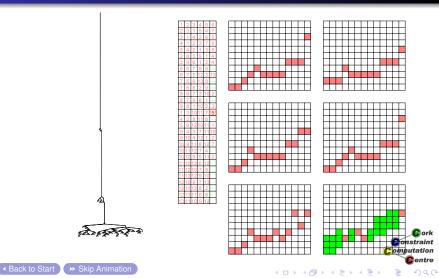


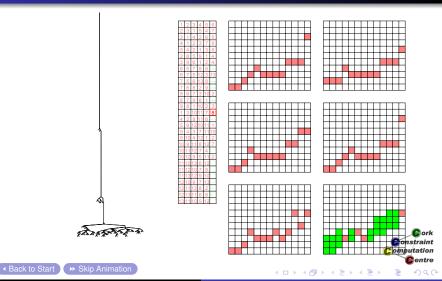




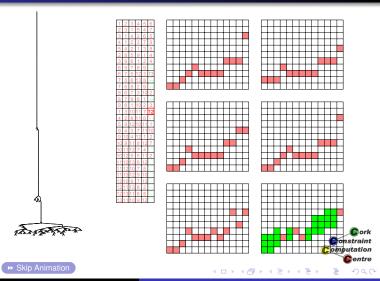


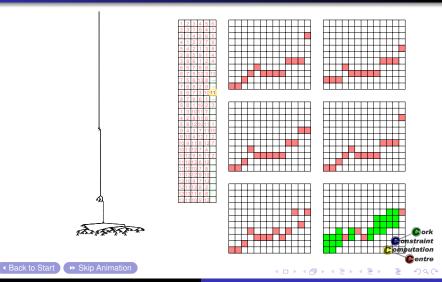


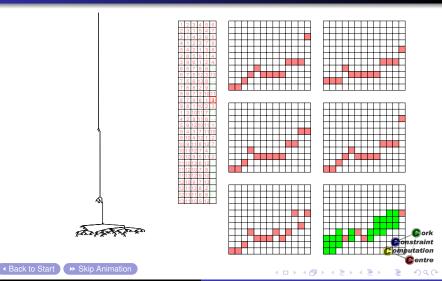


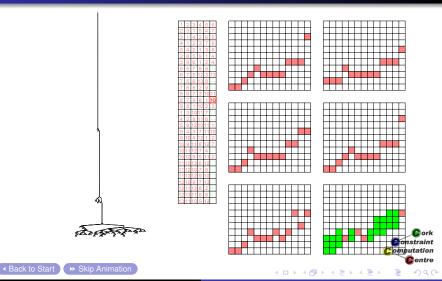


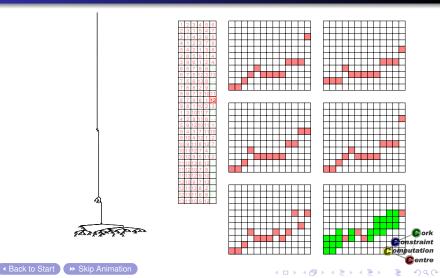
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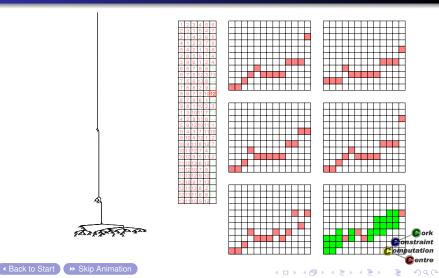


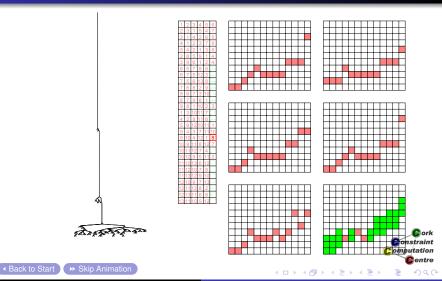


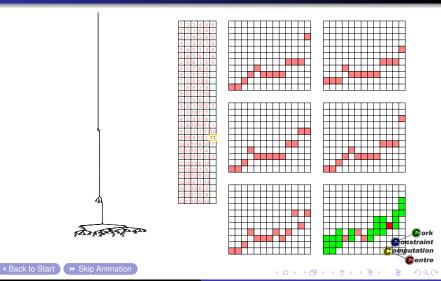




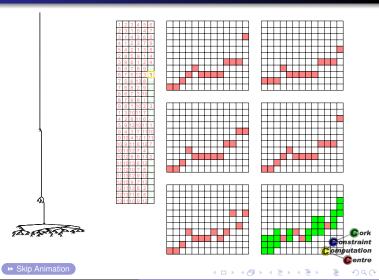




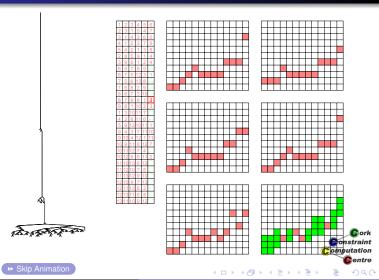


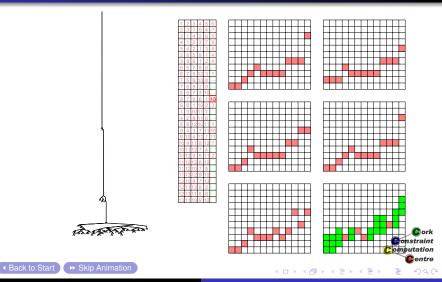


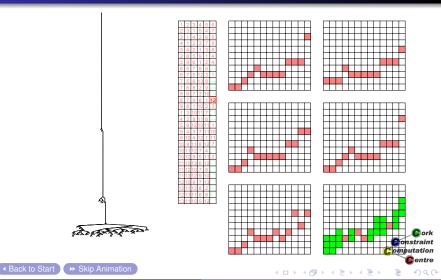
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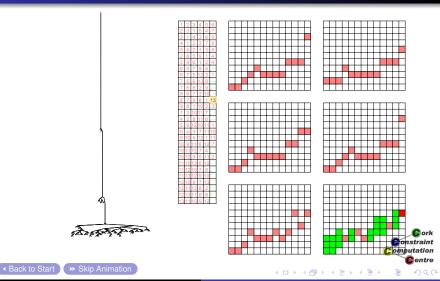


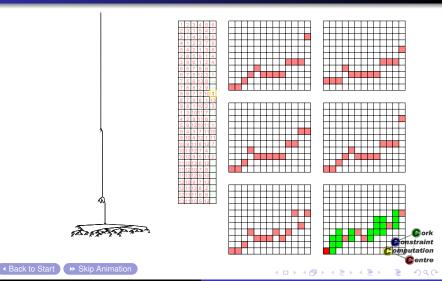
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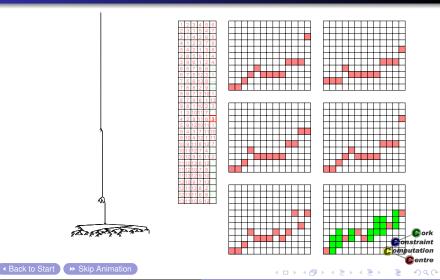


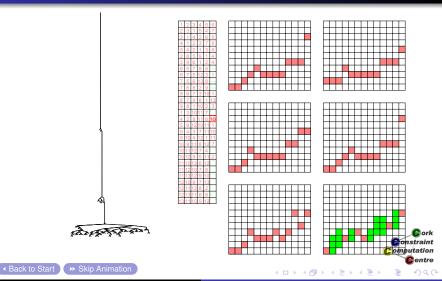


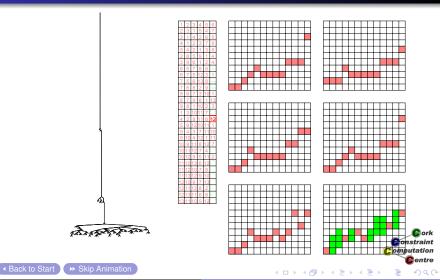


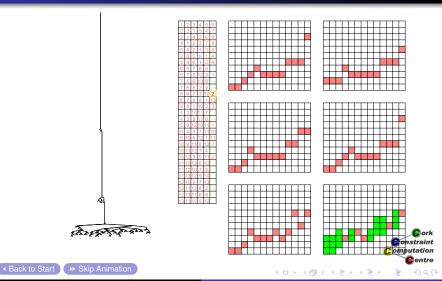


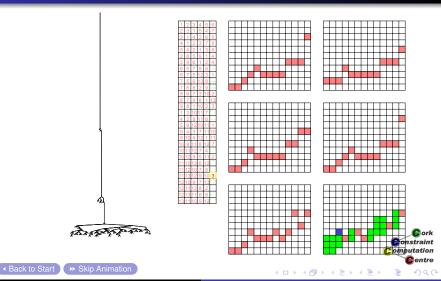


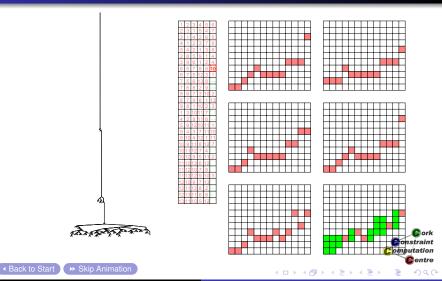


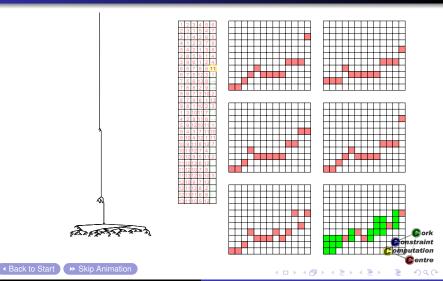


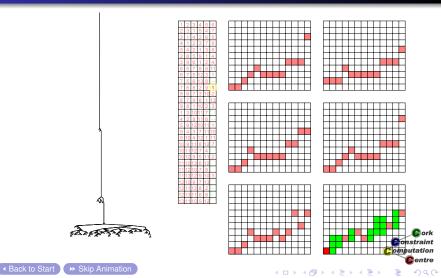


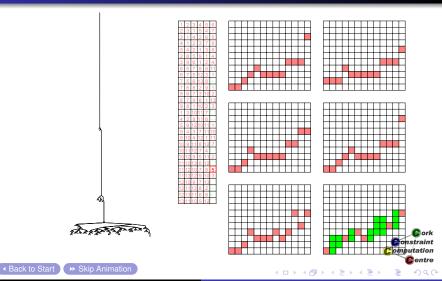


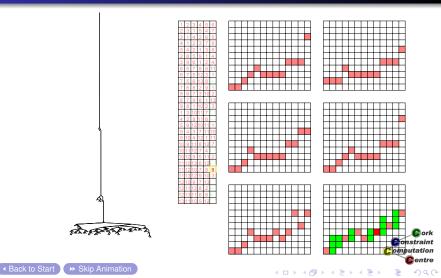


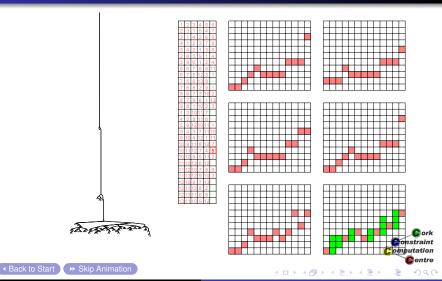


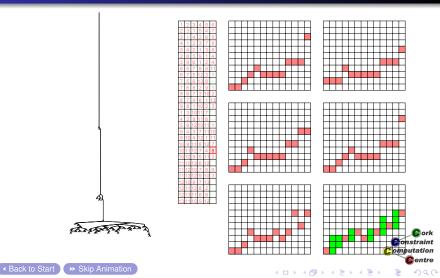


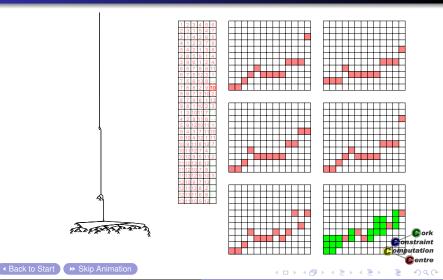


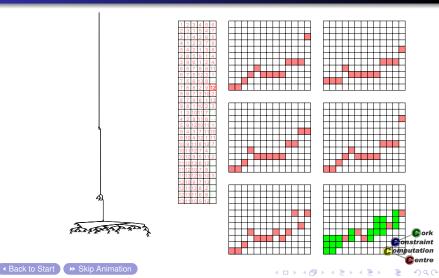


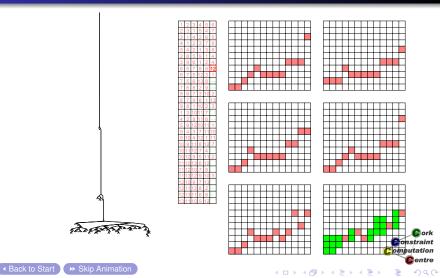


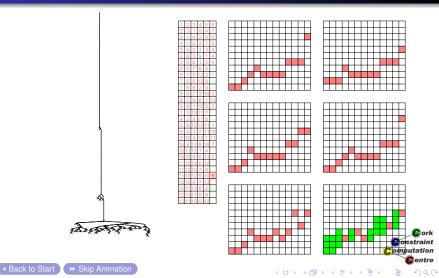


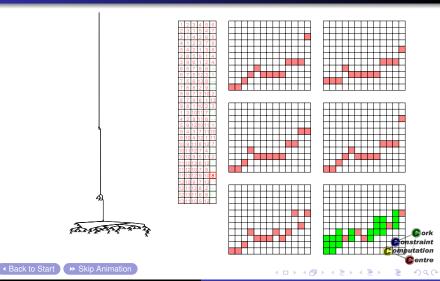


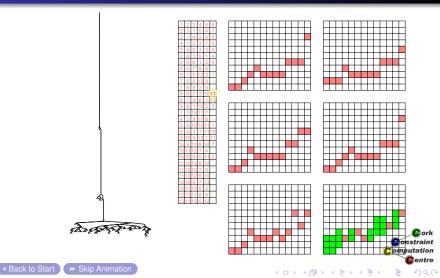


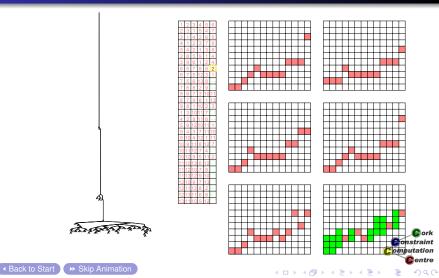


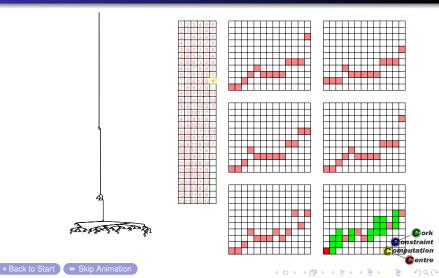


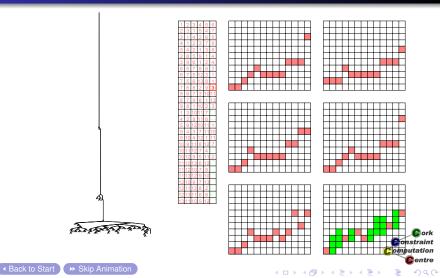


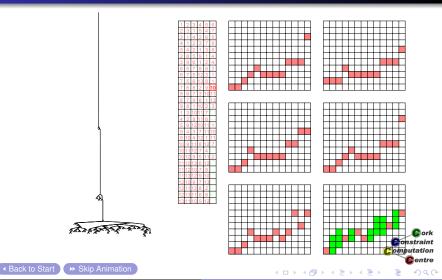


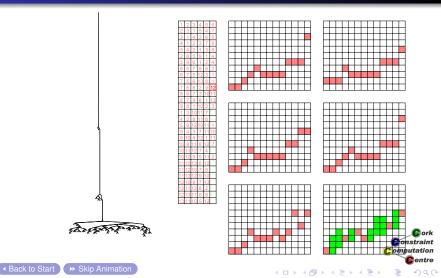


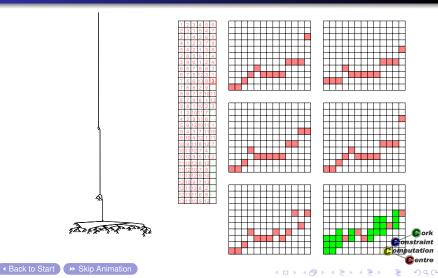


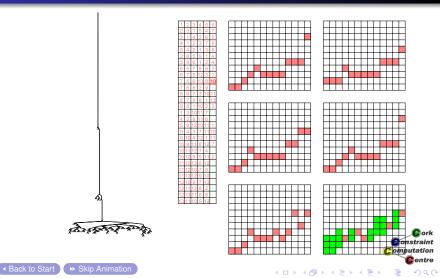


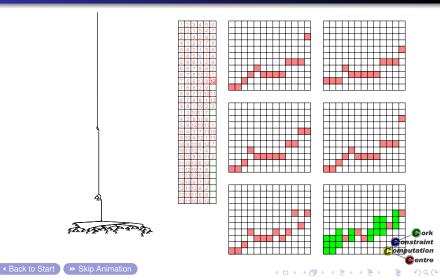


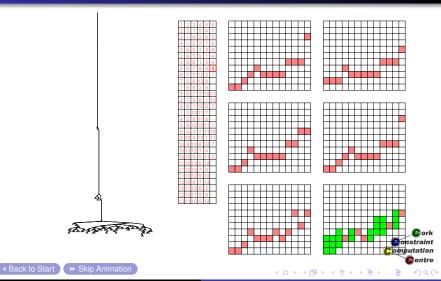


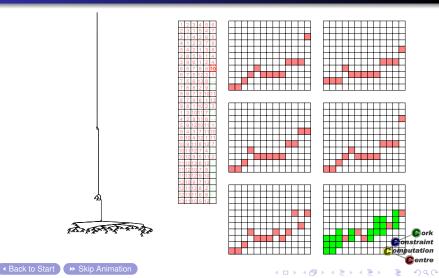


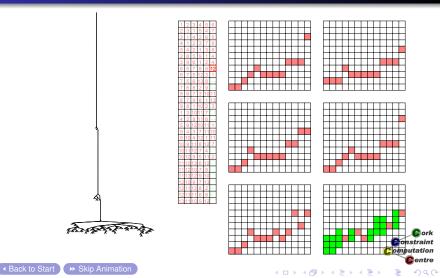


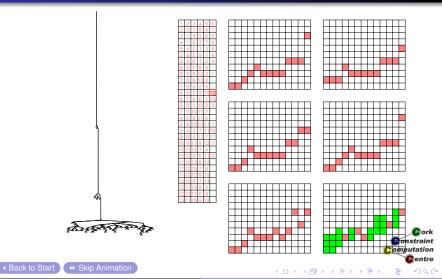


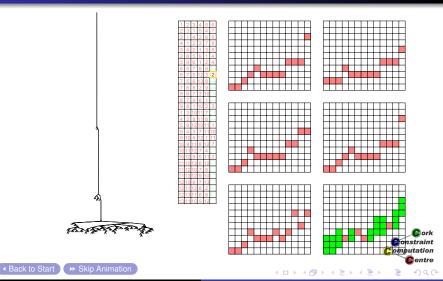


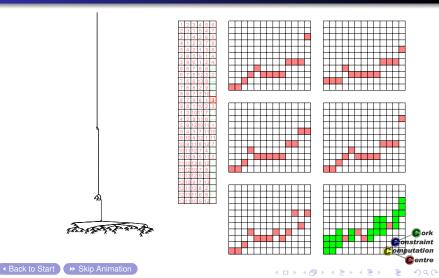


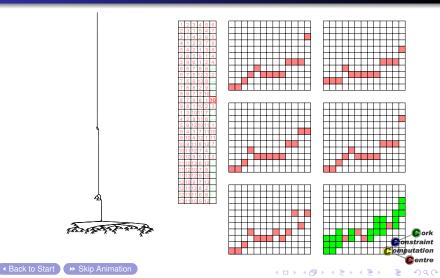


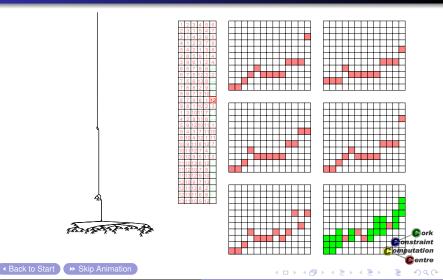


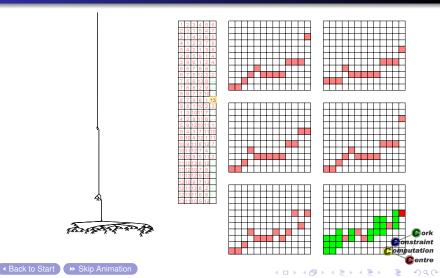




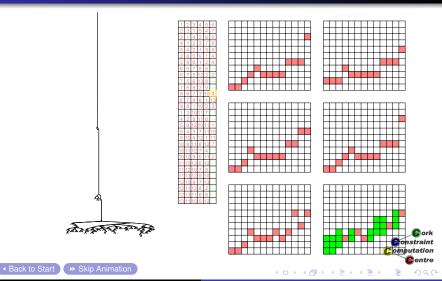


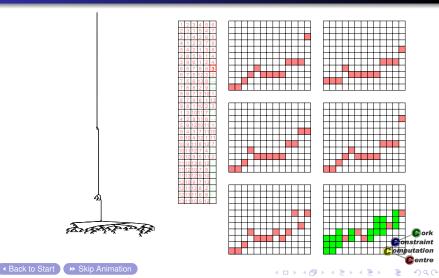


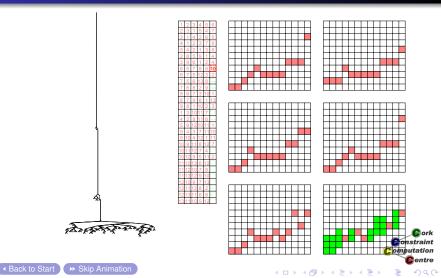


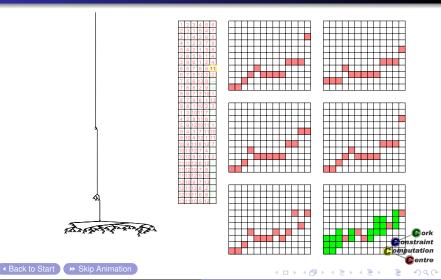


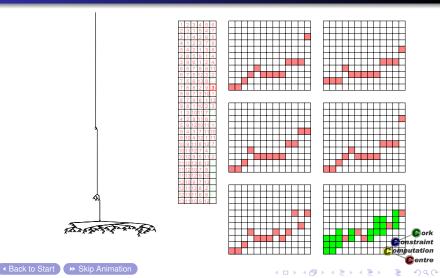
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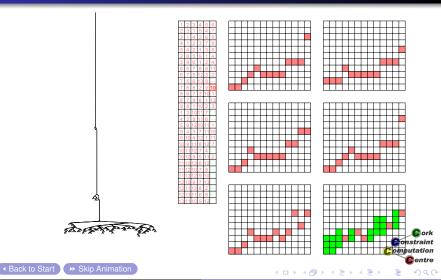


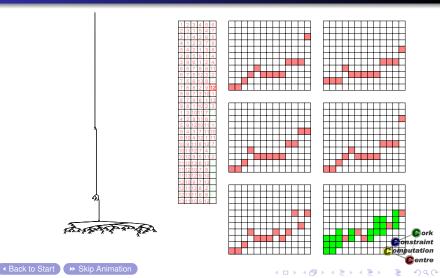


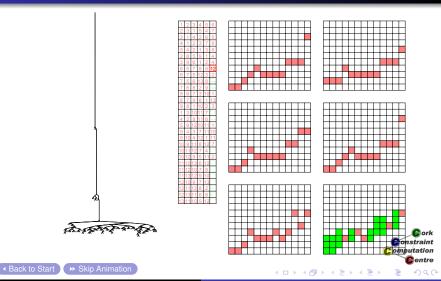


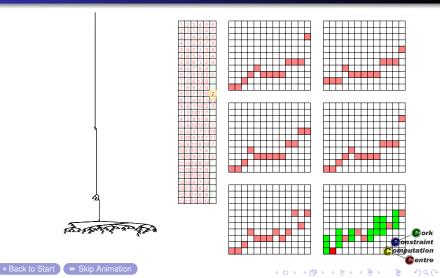


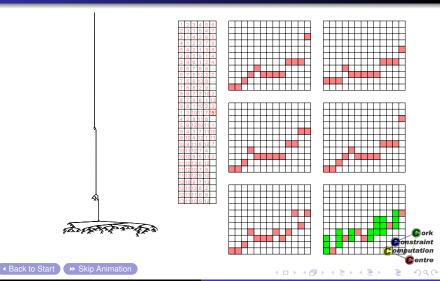


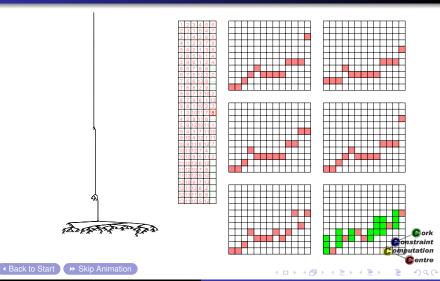


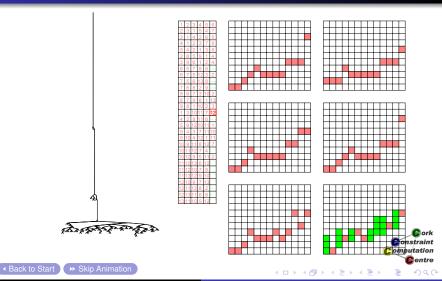


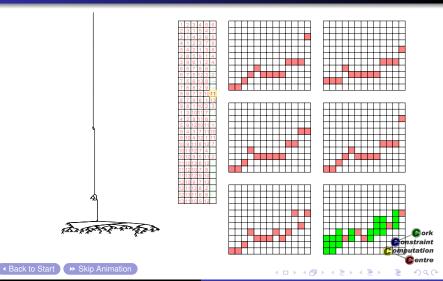


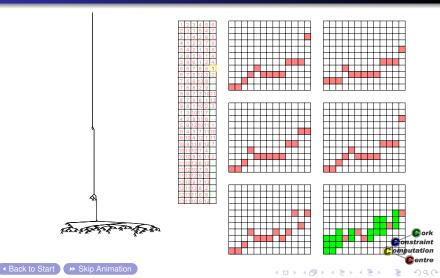


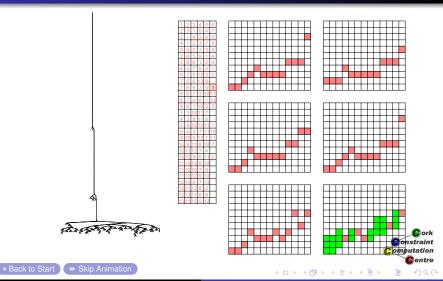


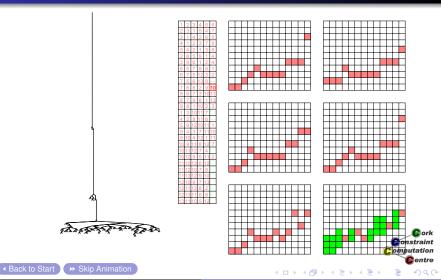


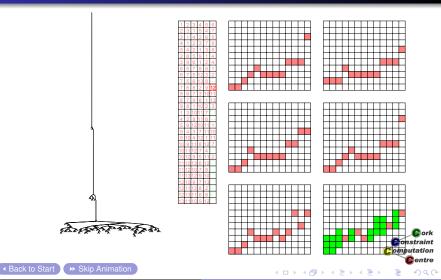


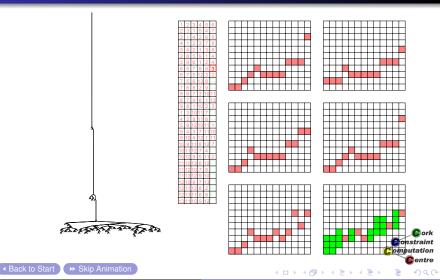


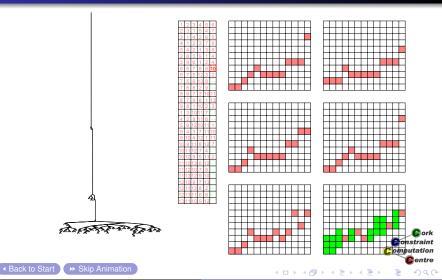


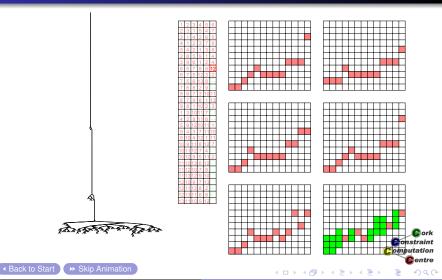


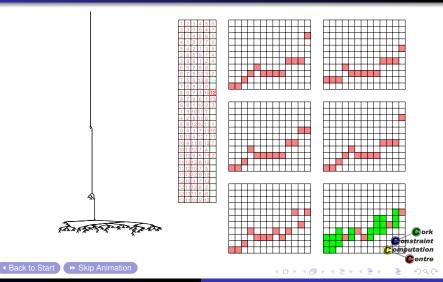


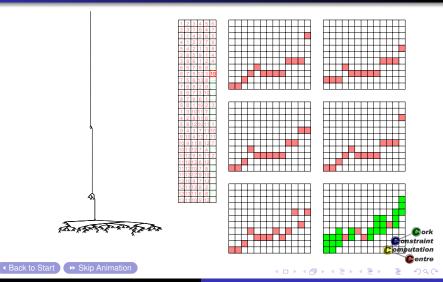


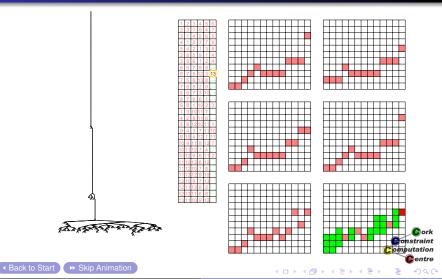


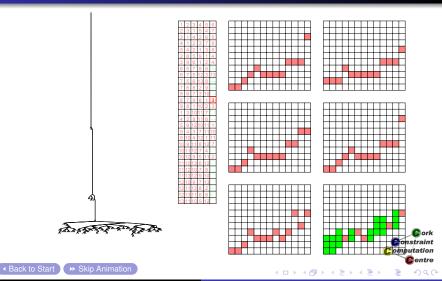


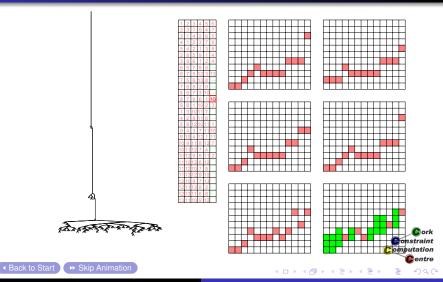


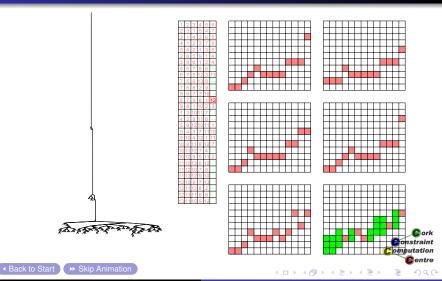


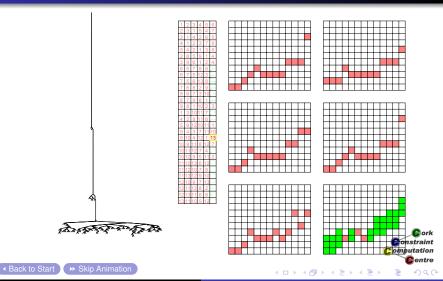


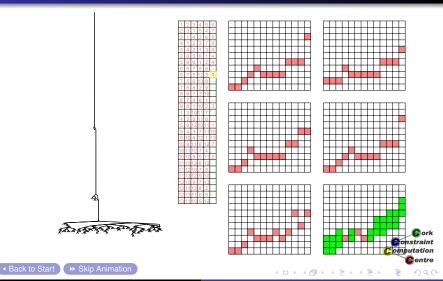


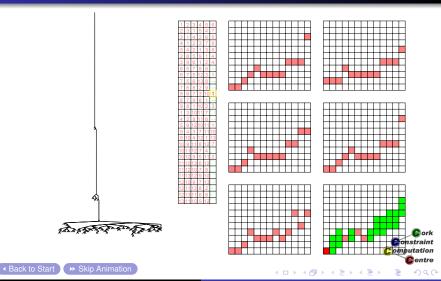


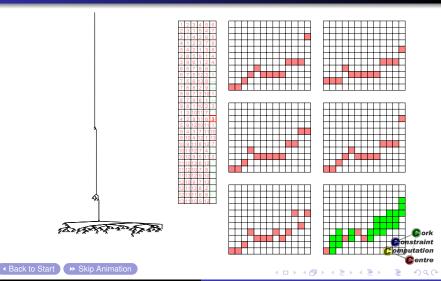


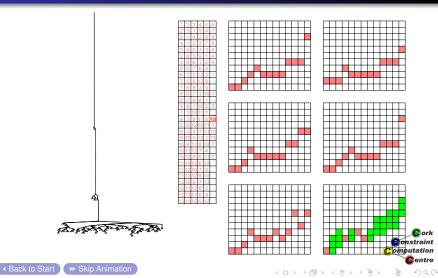


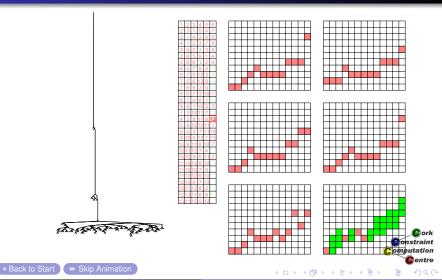


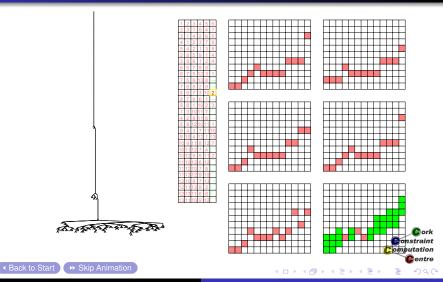


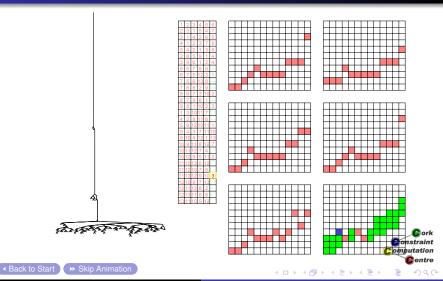


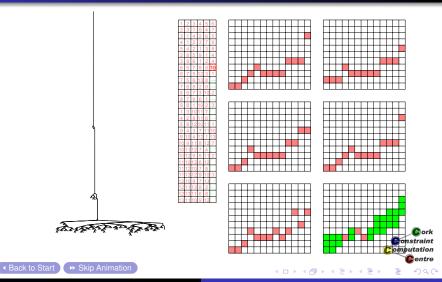


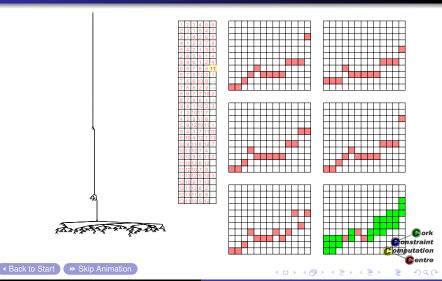


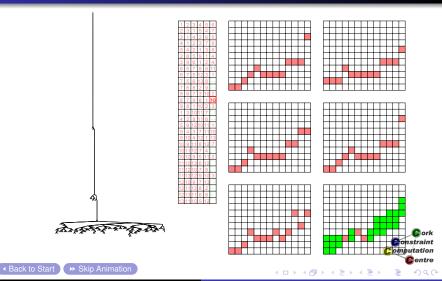


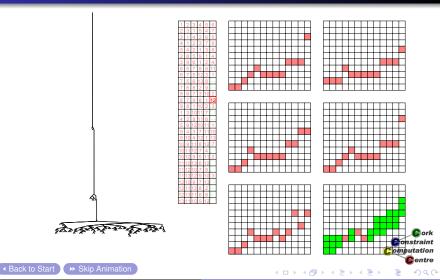


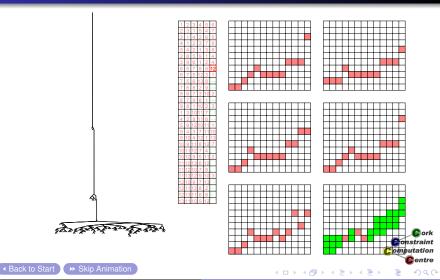


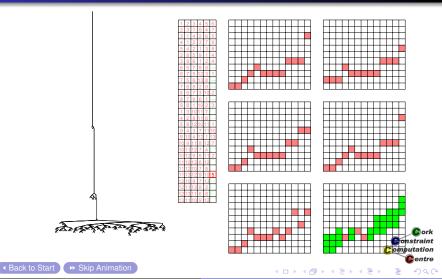


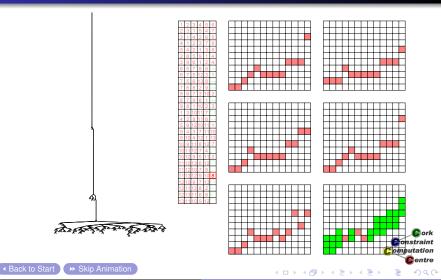


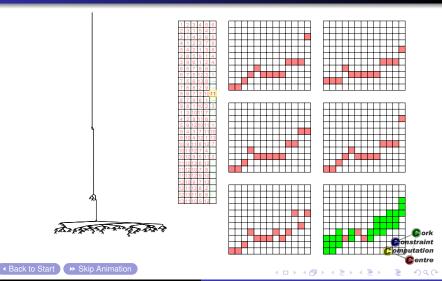


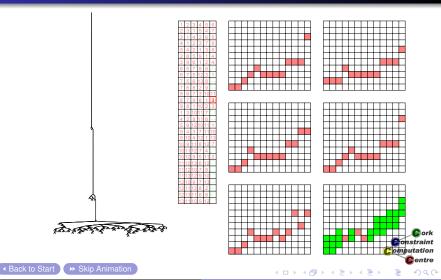


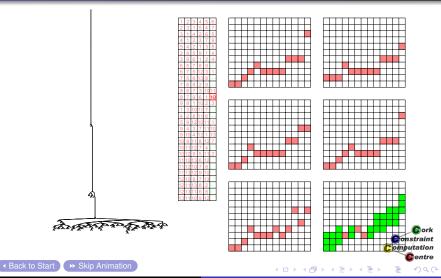


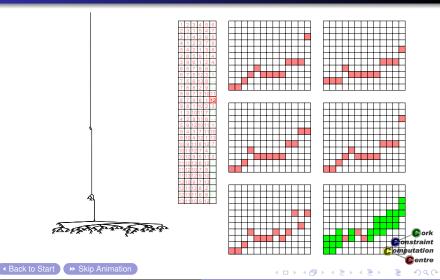


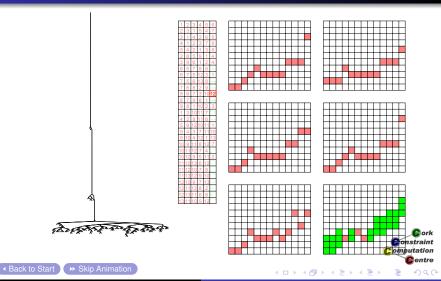


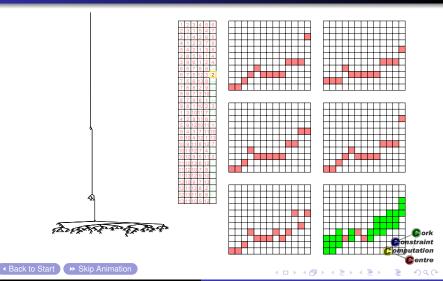


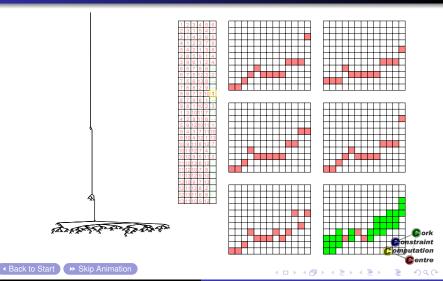


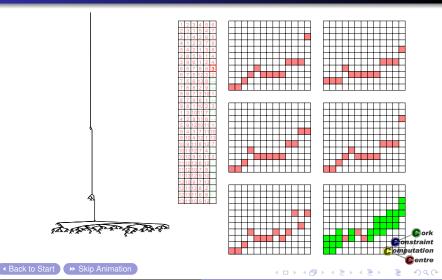


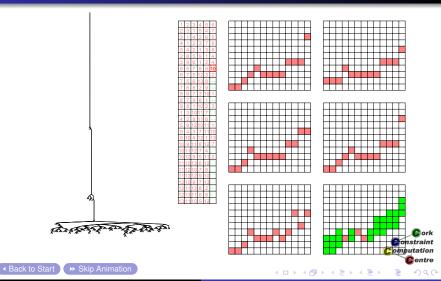


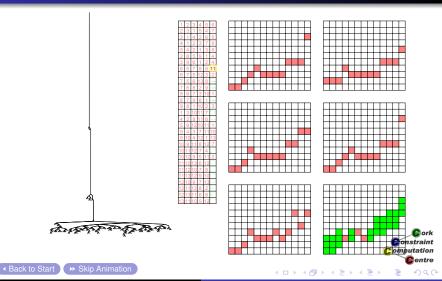


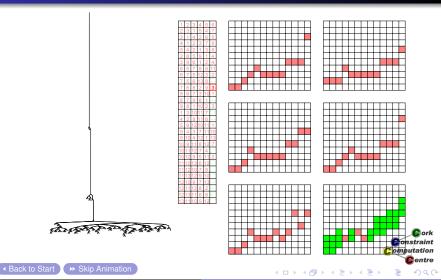


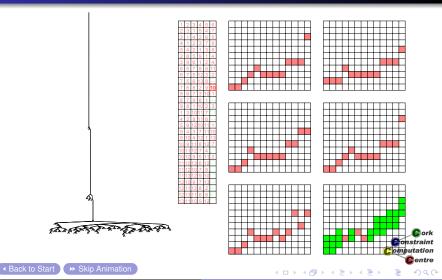


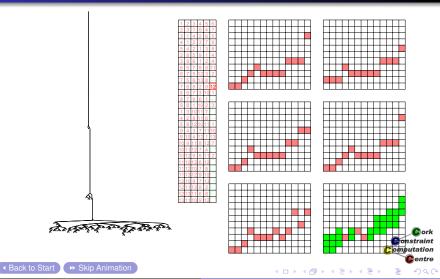


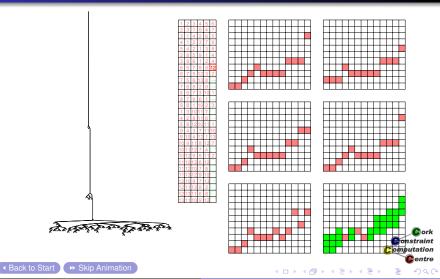


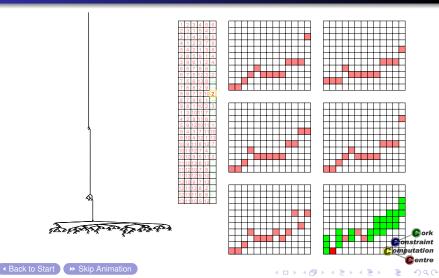


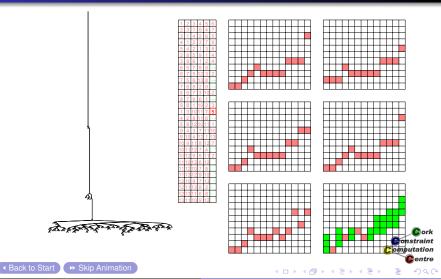


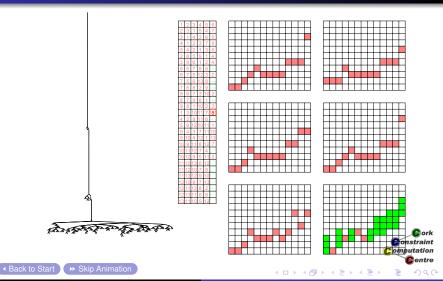


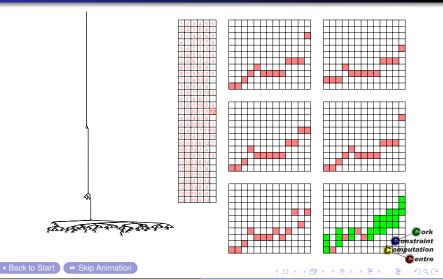


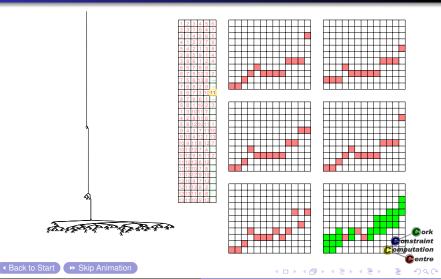


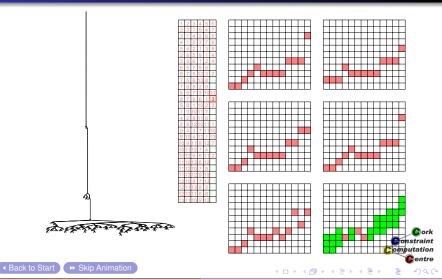


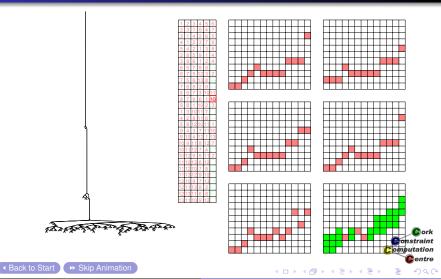


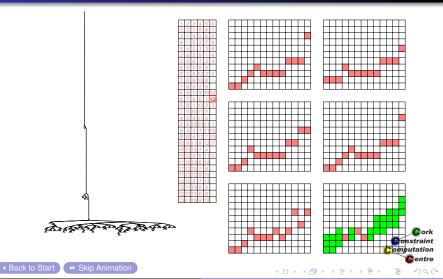


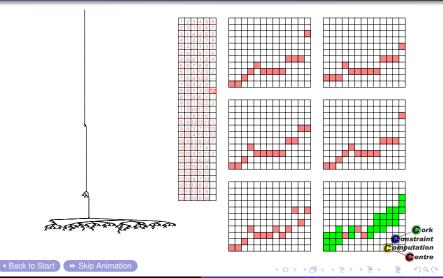


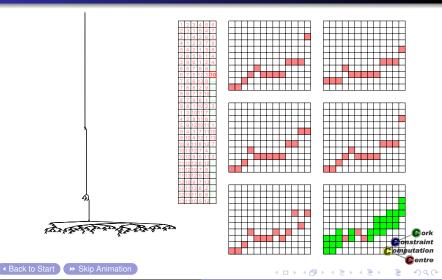


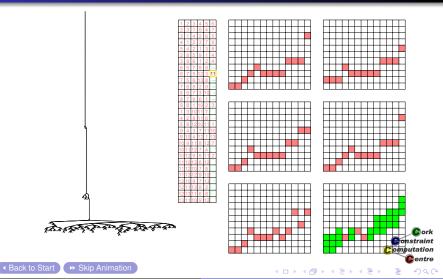


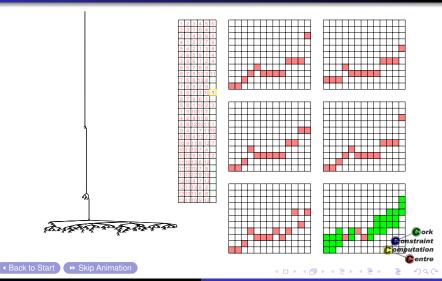


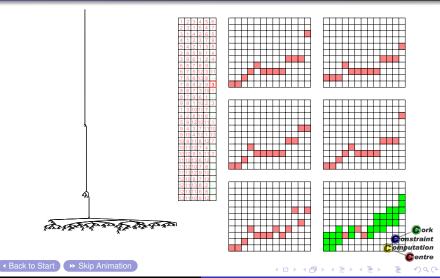


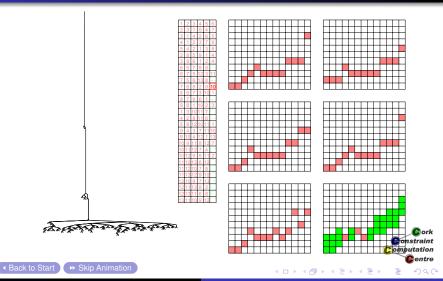


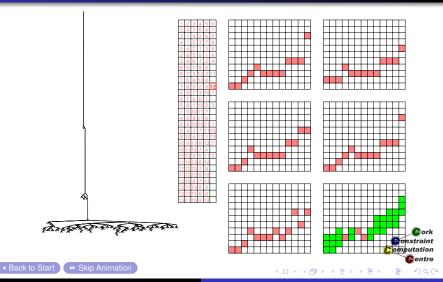


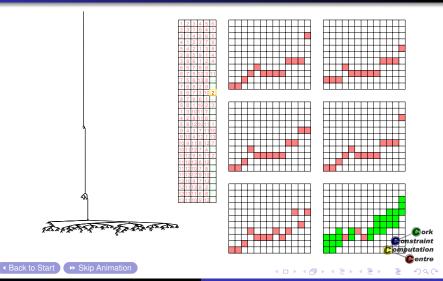


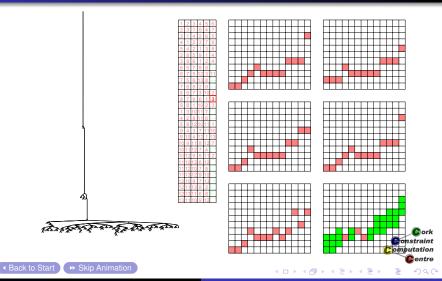


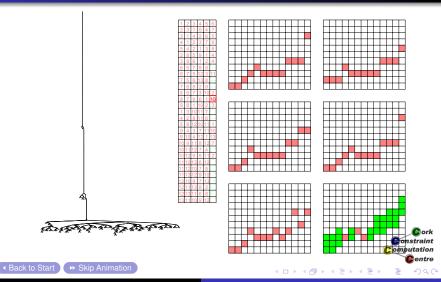


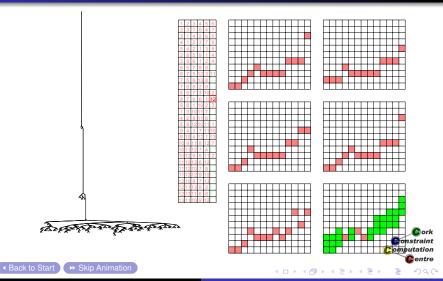


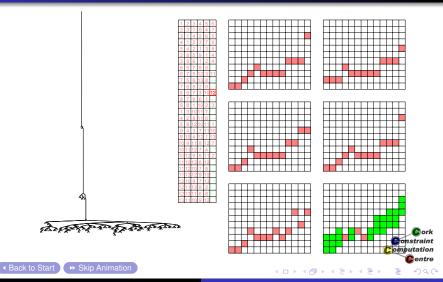


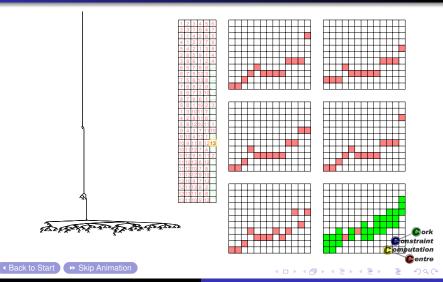


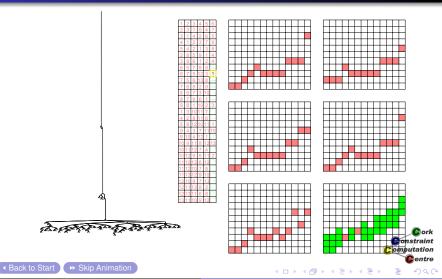


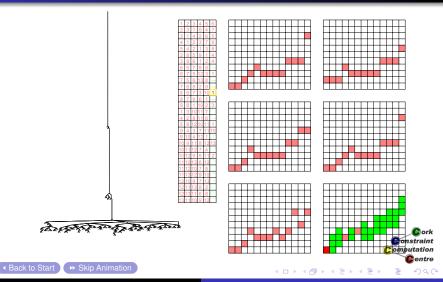


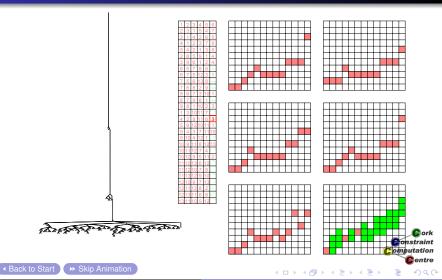


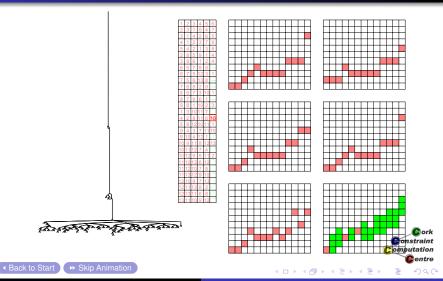


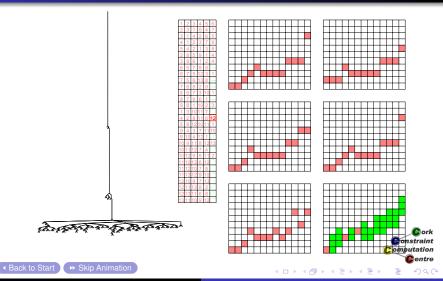


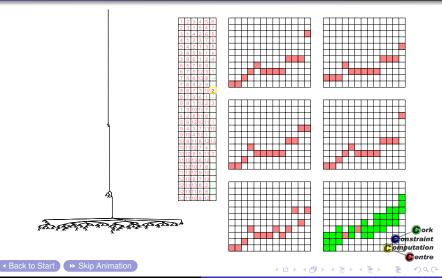


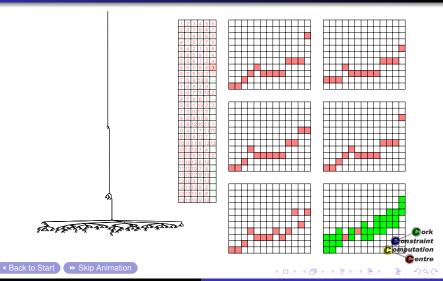


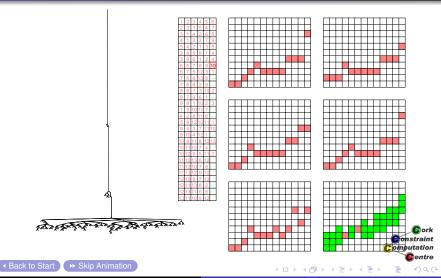


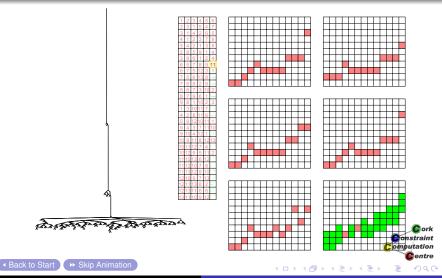


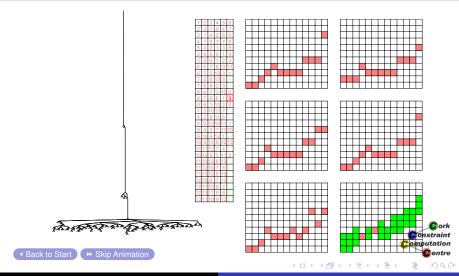


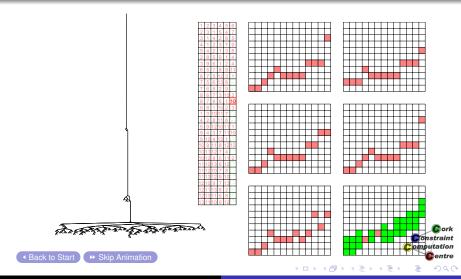


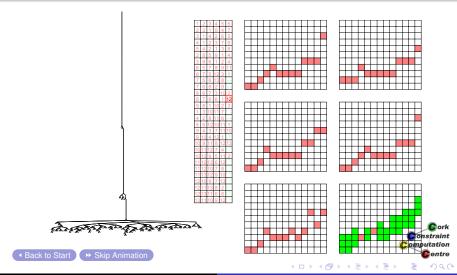


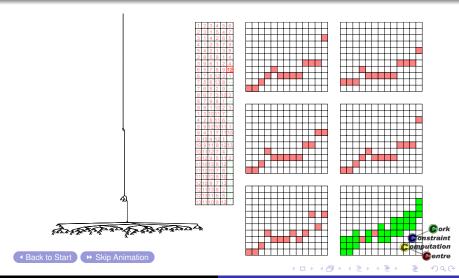


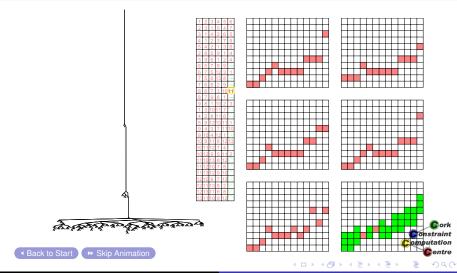


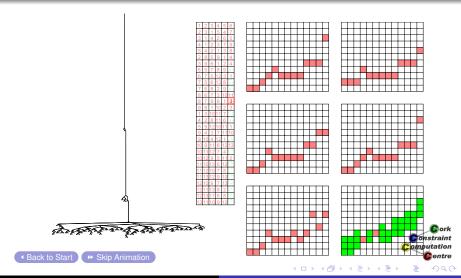


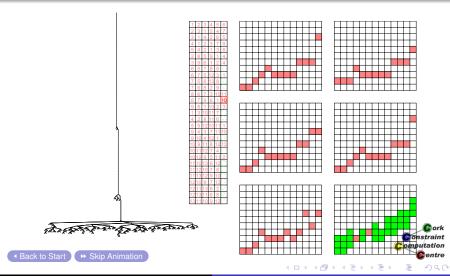


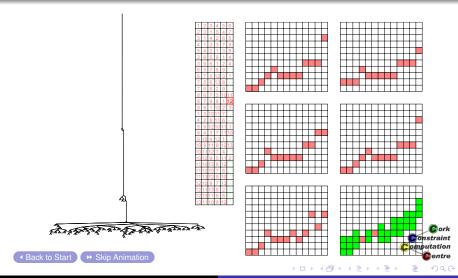


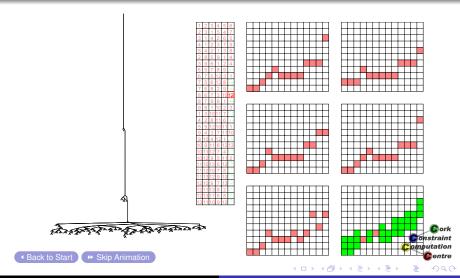


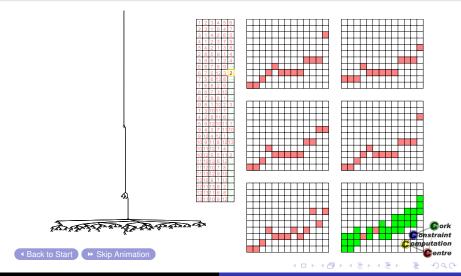


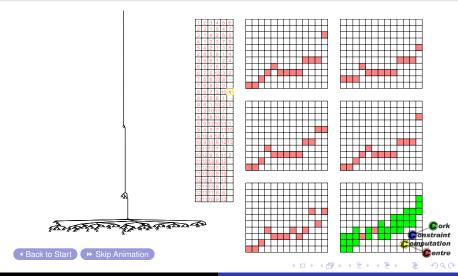


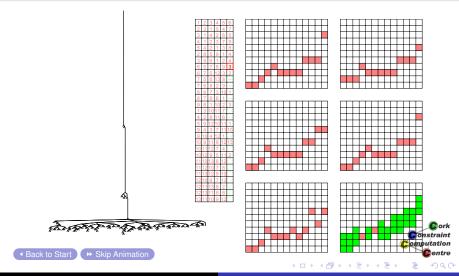


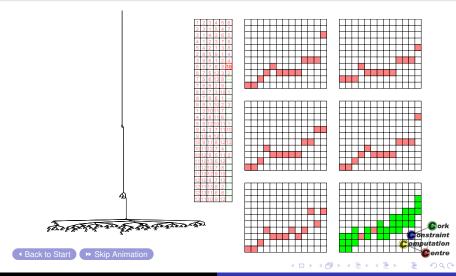


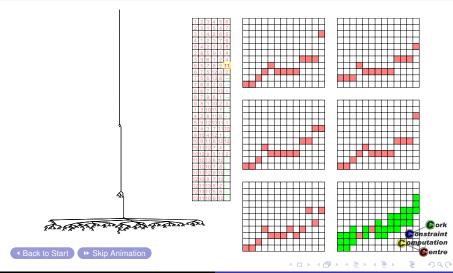


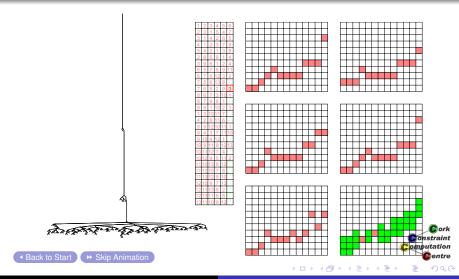


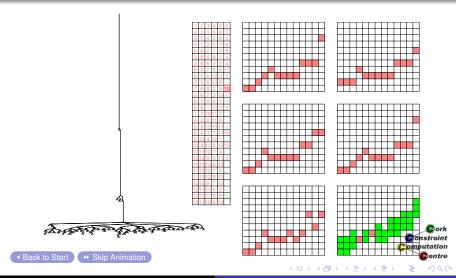


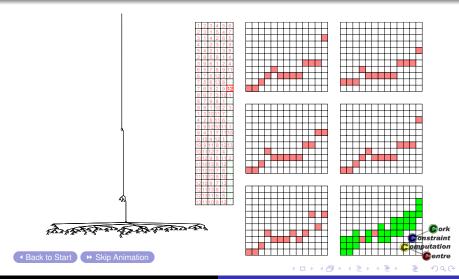


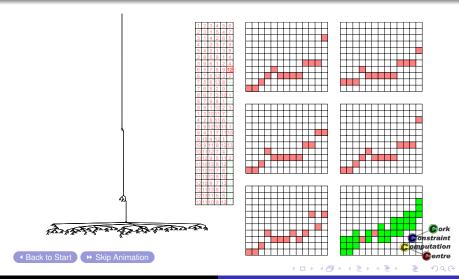


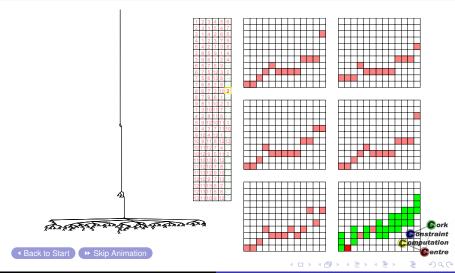


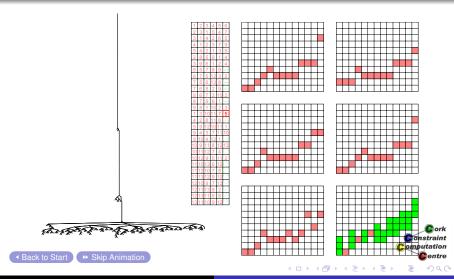


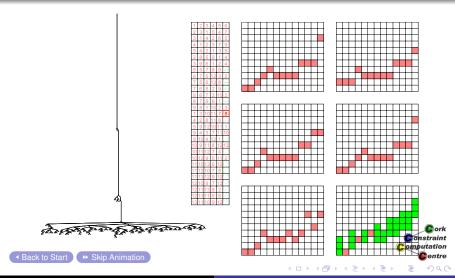


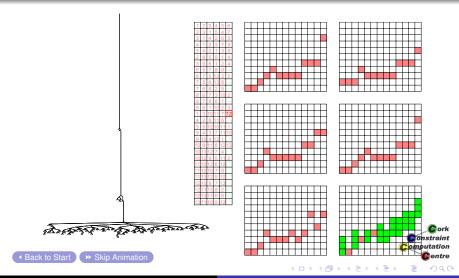


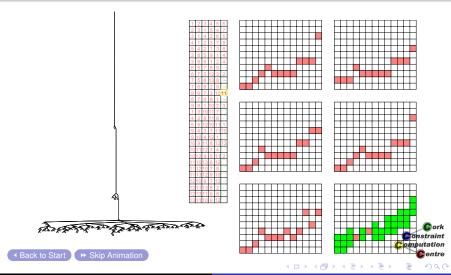


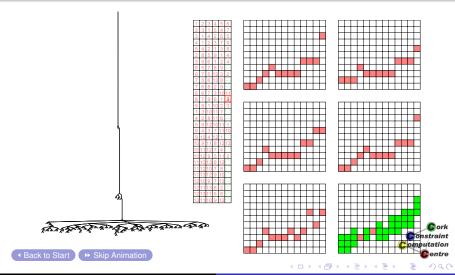


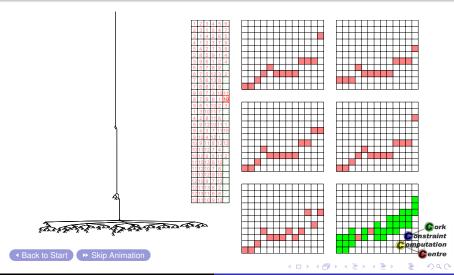


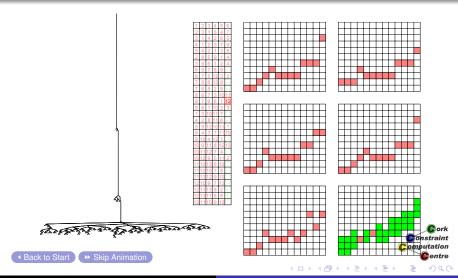


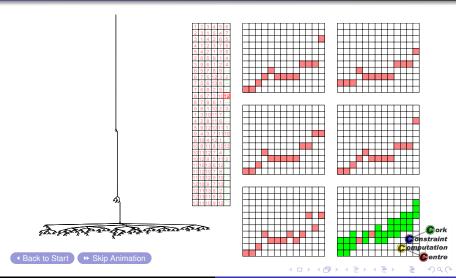


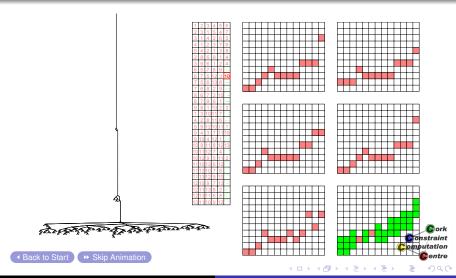


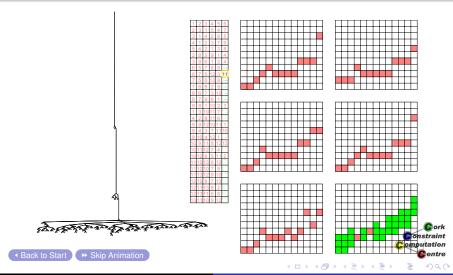


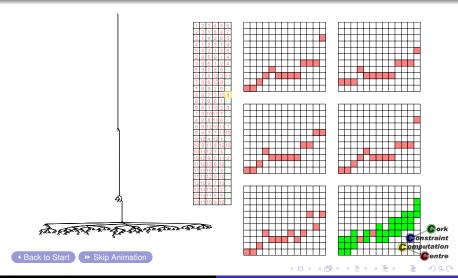


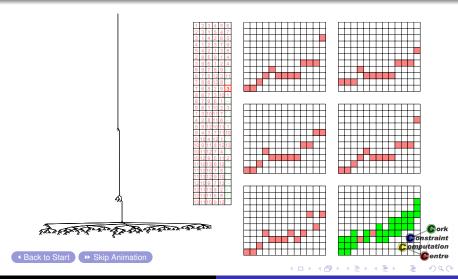


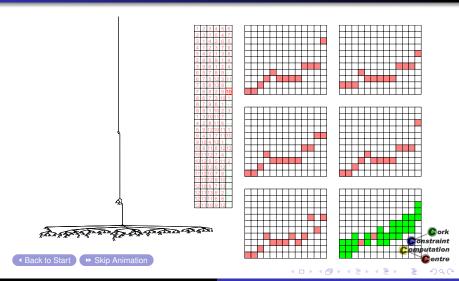


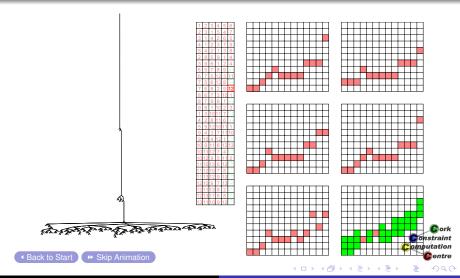


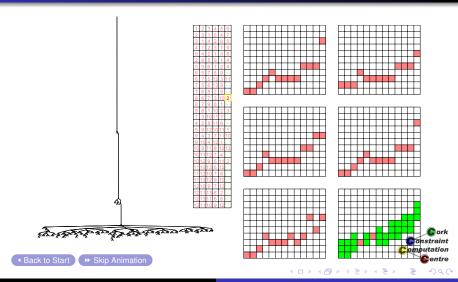


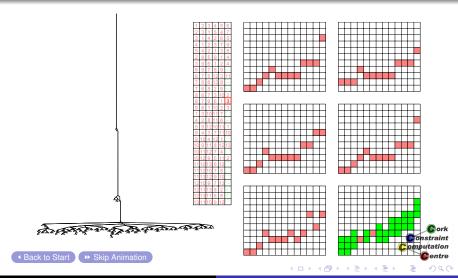


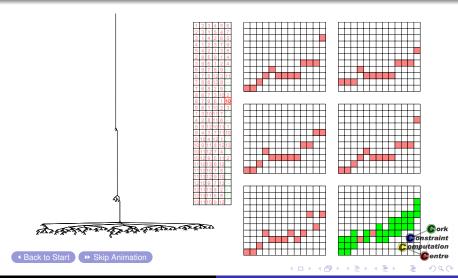


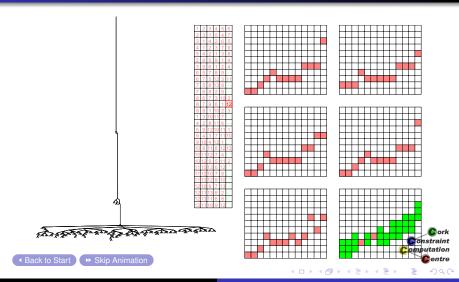


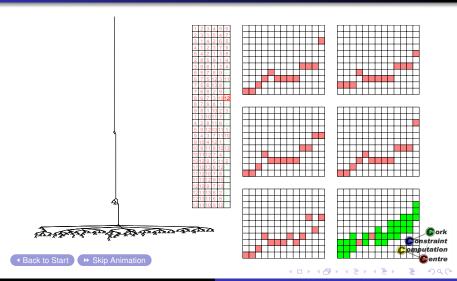


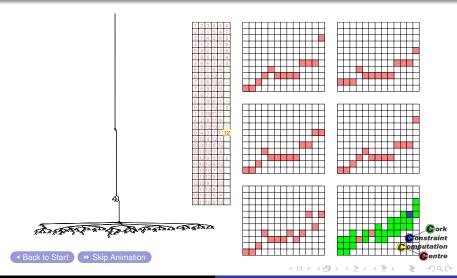


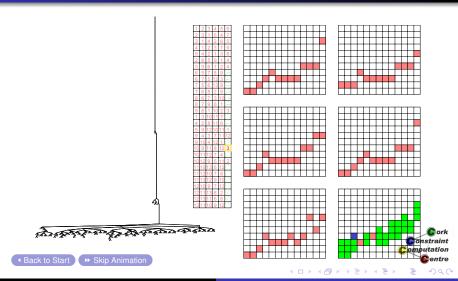


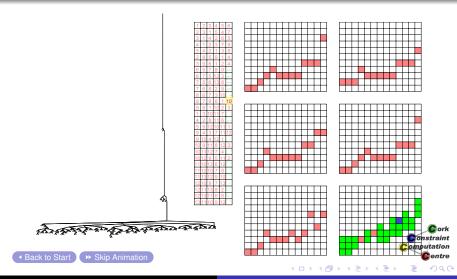


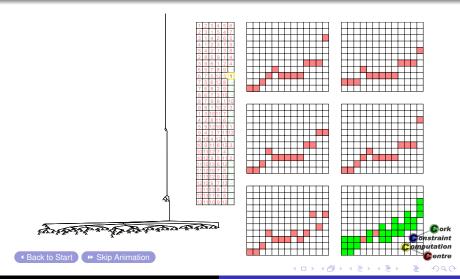


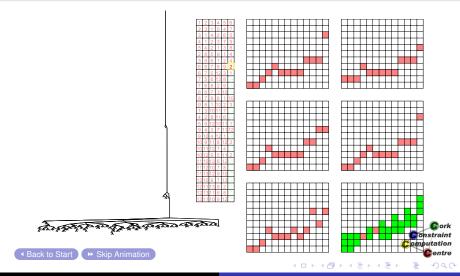


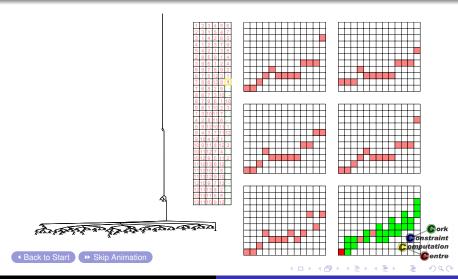


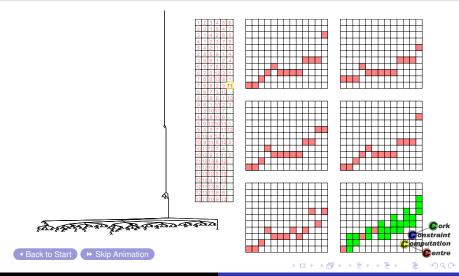


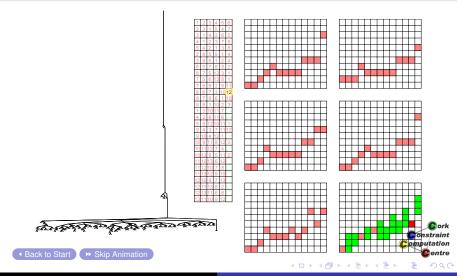


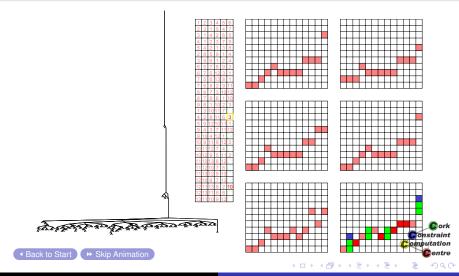


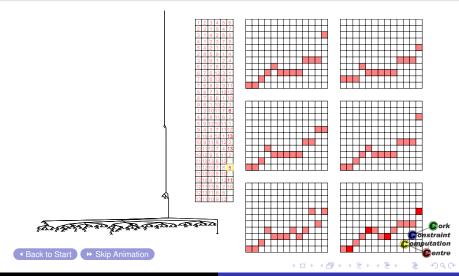


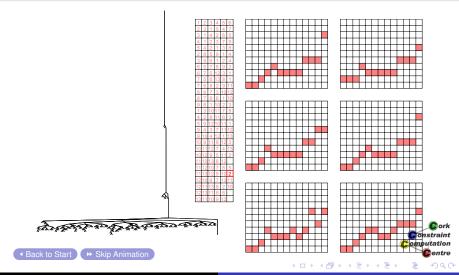


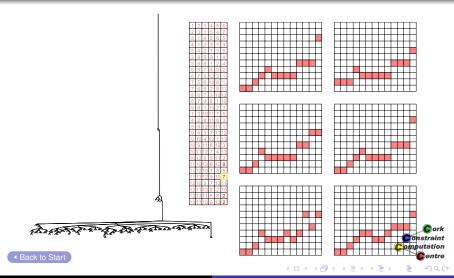




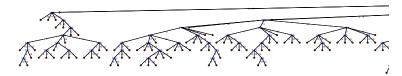








Layered Solution (Zoomed)





Observations

- Deep backtracking for last time period
- No backtracking to earlier time periods required
- Small amount of backtracking at other time periods



Idea

- Use credit based search
- But not for complete search tree
- Loose too much useful work
- Backtrack independently for each time period
- Hope to correct wrong choices without deep backtracking



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Reminder: Credit Based Search

- Explore top of tree completely, based on credit
- Start with fixed amount of credit
- Each node consumes one credit unit
- Split remaining credit amongst children
- When credit runs out, start bounded backtrack search
- Each branch can use only K backtracks
- If this limit is exceeded, jump to unexplored top of tree



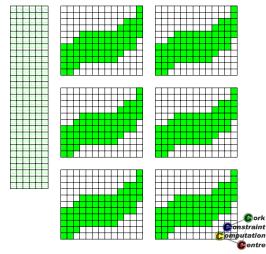


Layered with Credit

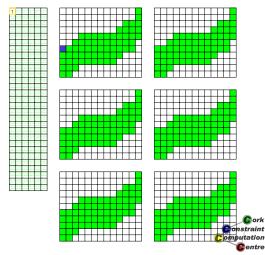


Layered with Credit Search

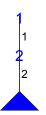


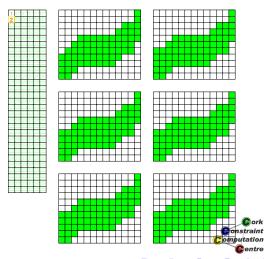




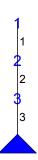


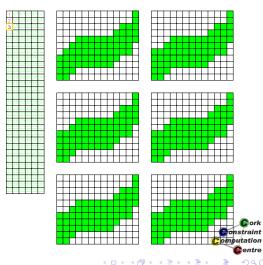


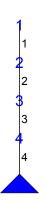


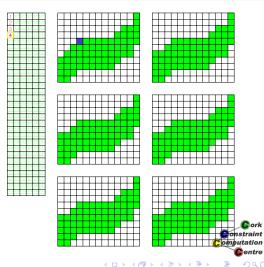




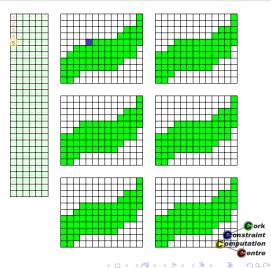




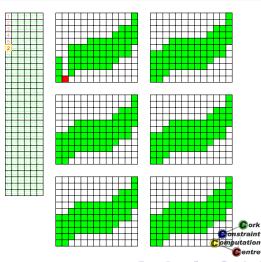




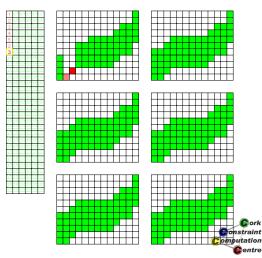






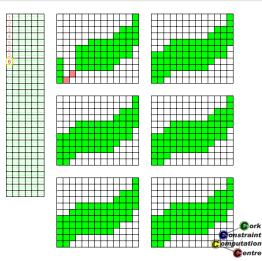




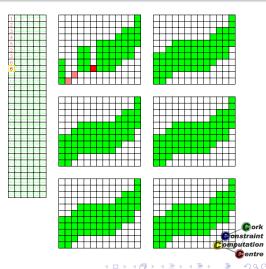




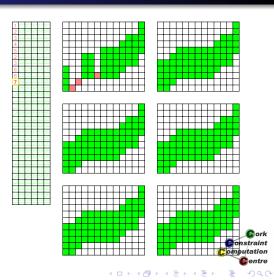




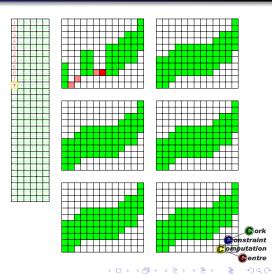




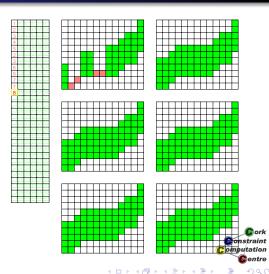






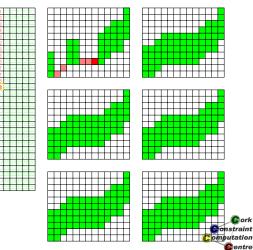




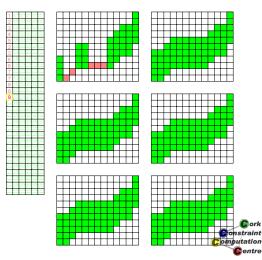




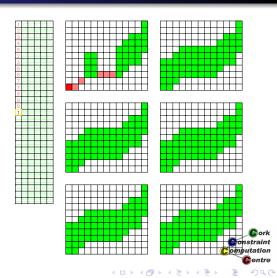






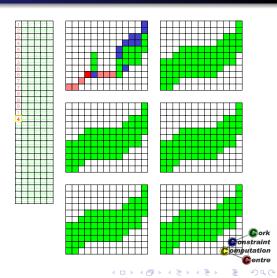






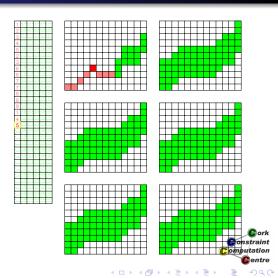






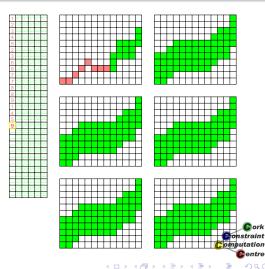




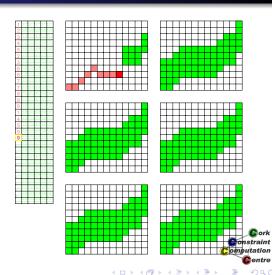






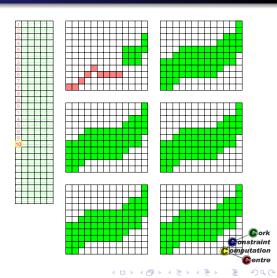






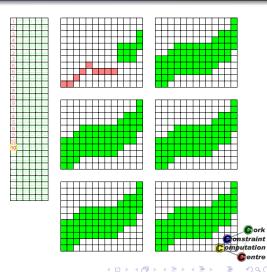






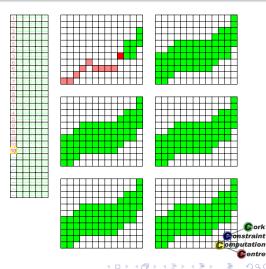




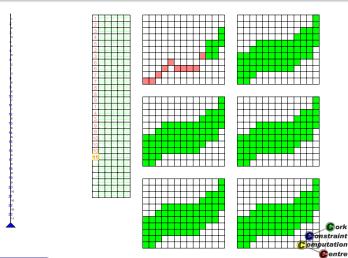






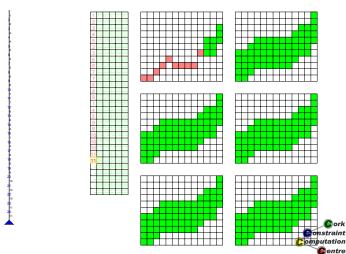


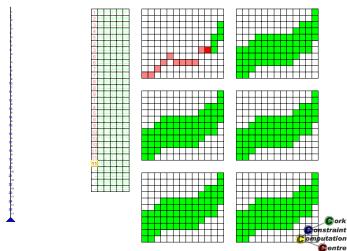


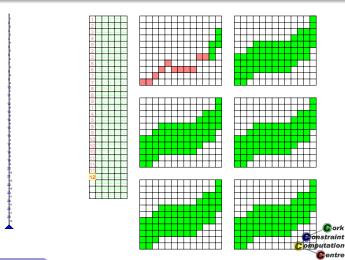




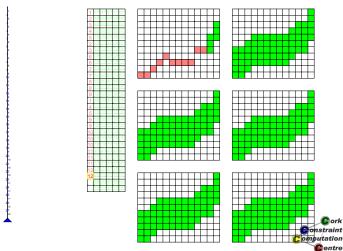




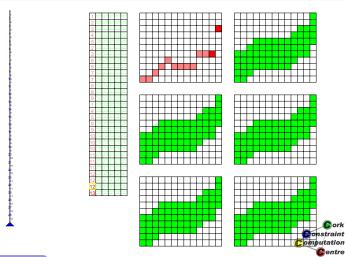


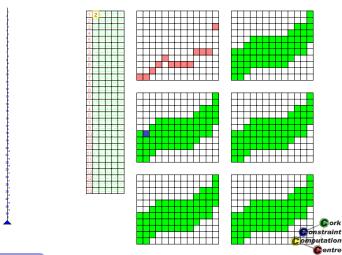






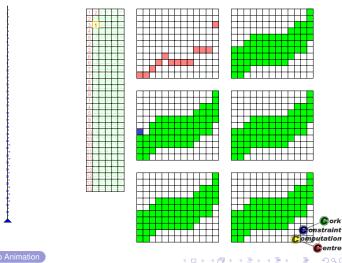


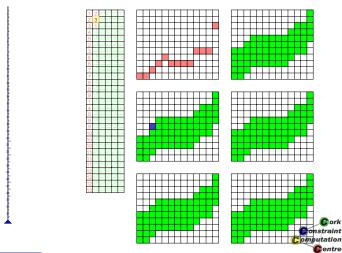




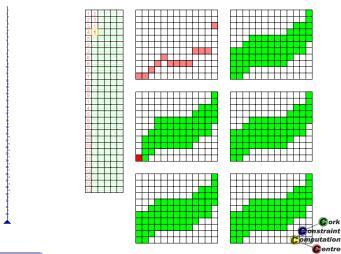


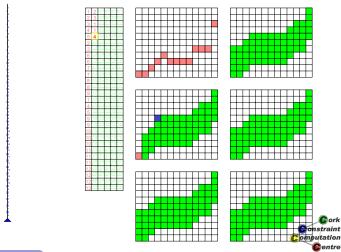
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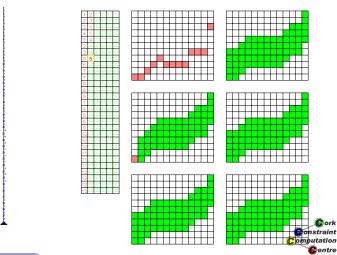


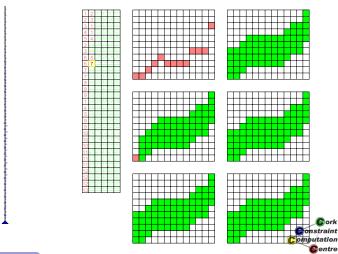


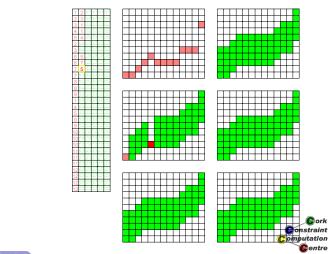


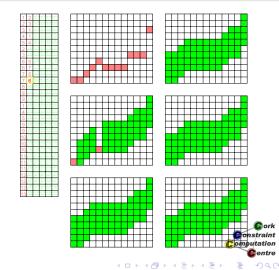


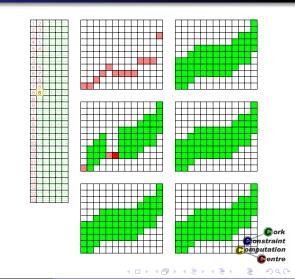




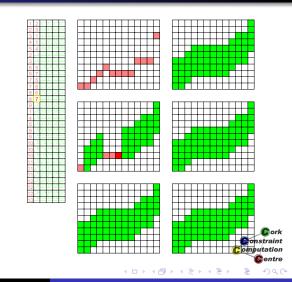


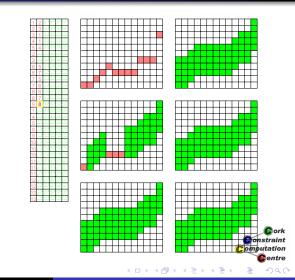


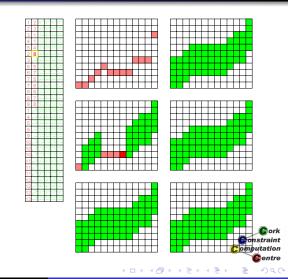






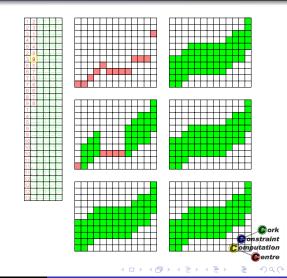


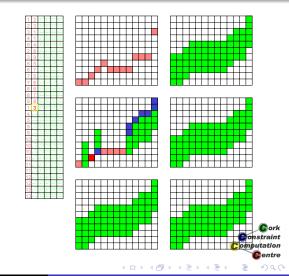




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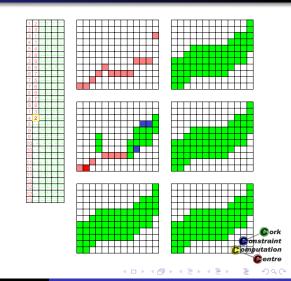
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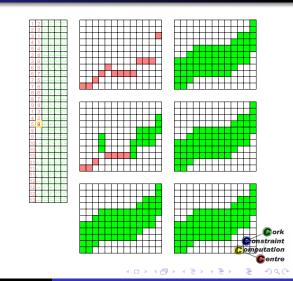




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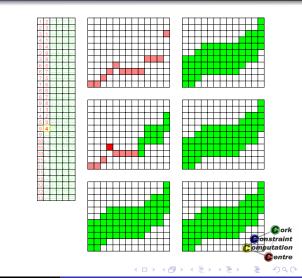
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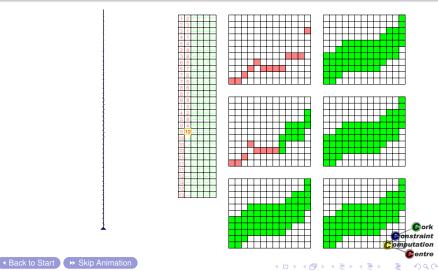


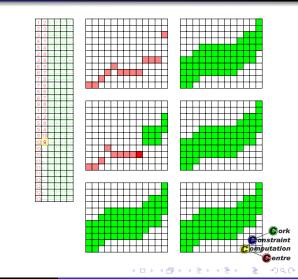


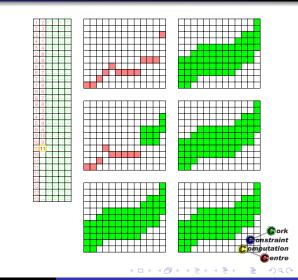
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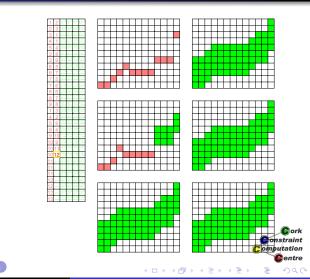
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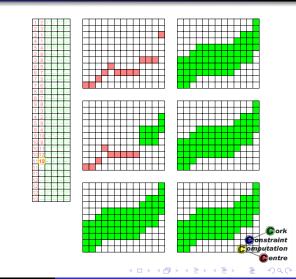


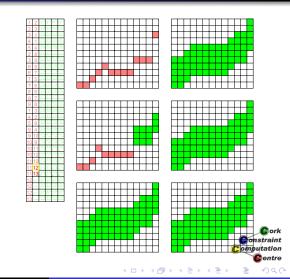




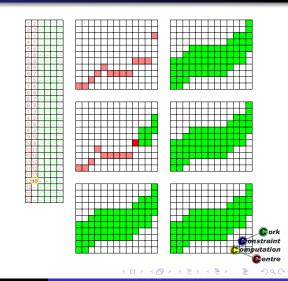


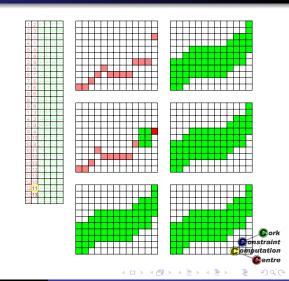


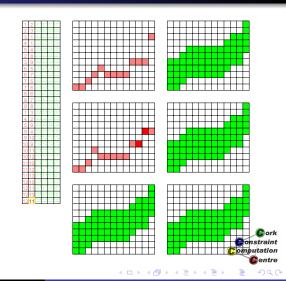


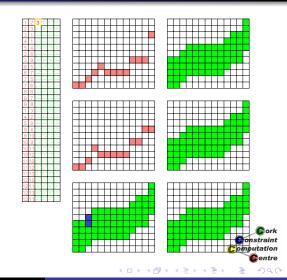


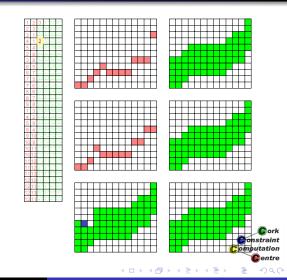


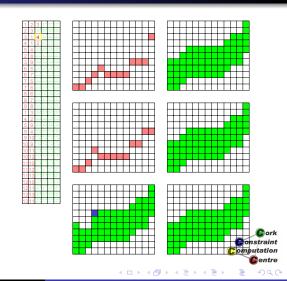


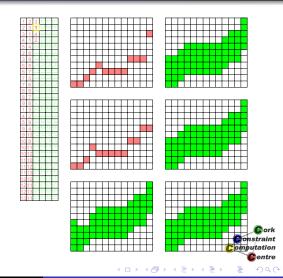


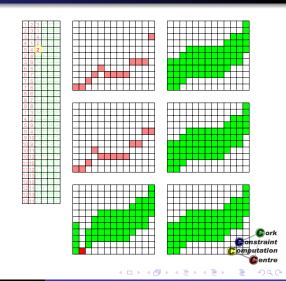


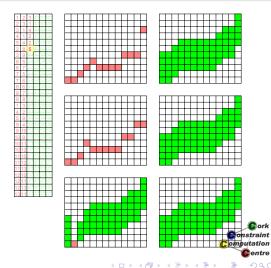




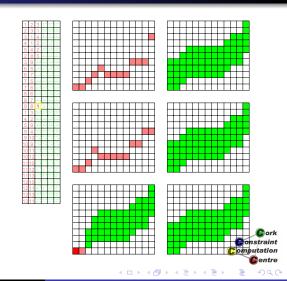




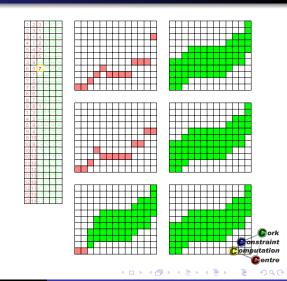




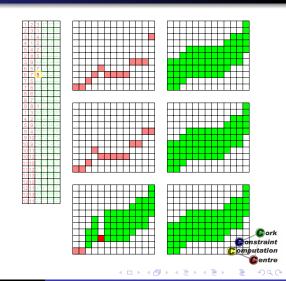
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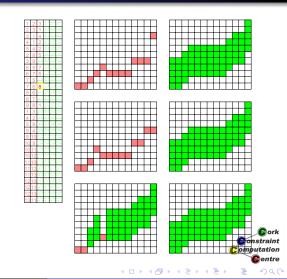


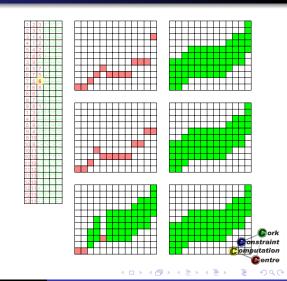




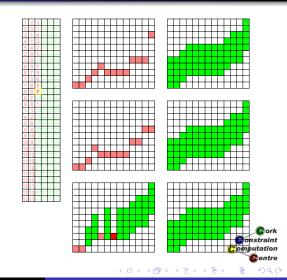


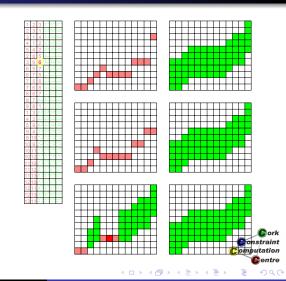




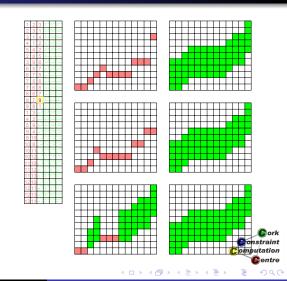


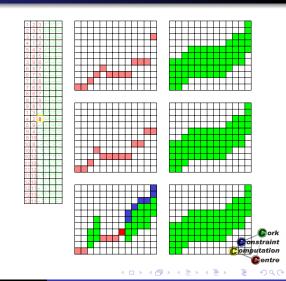


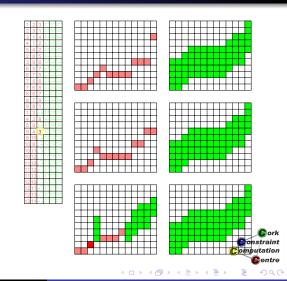


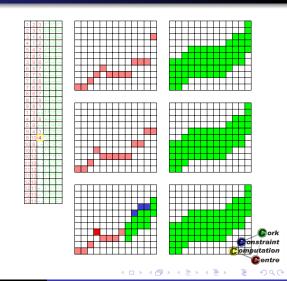




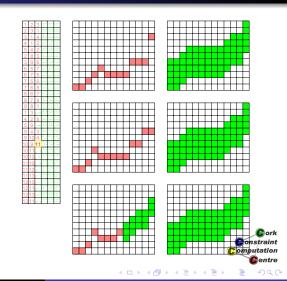


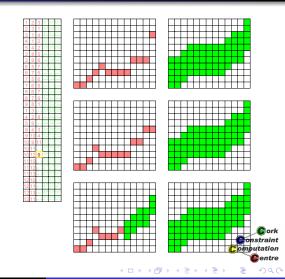




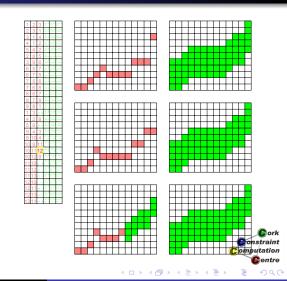




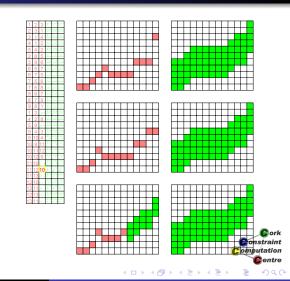


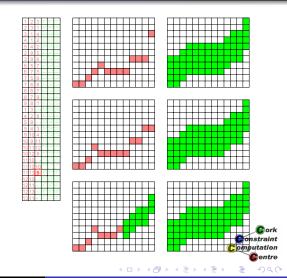


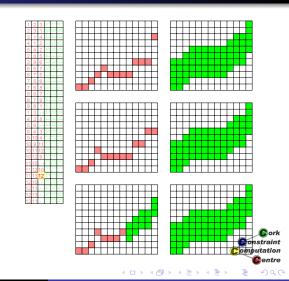


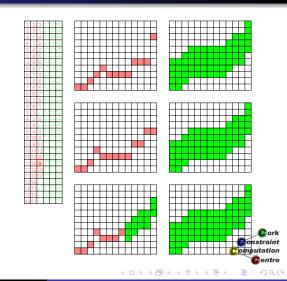


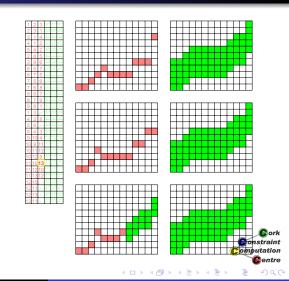




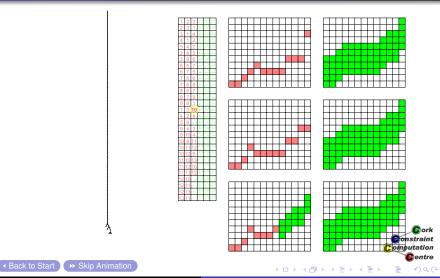


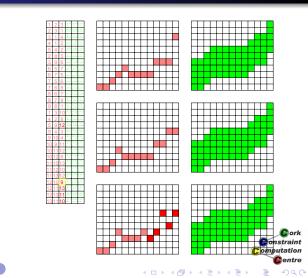




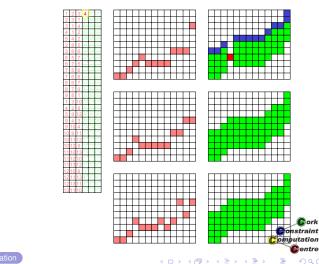


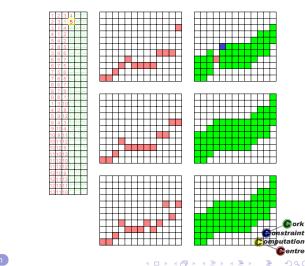


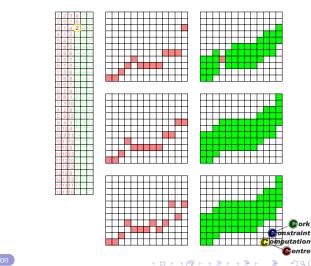






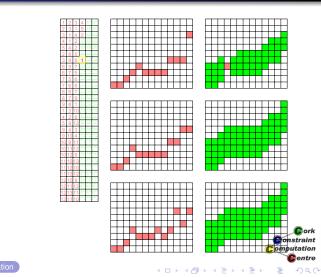


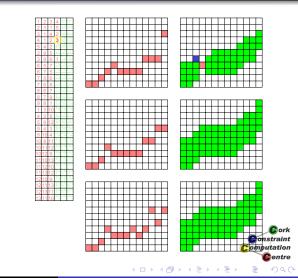




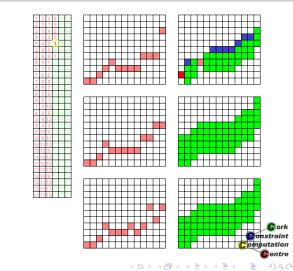






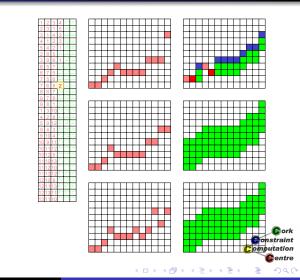


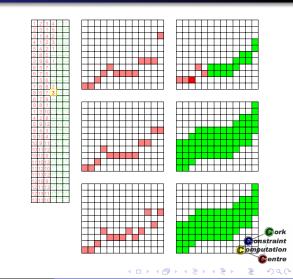


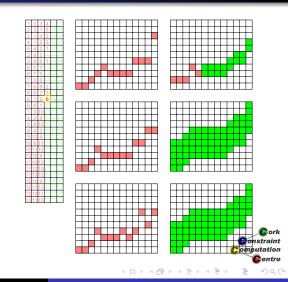


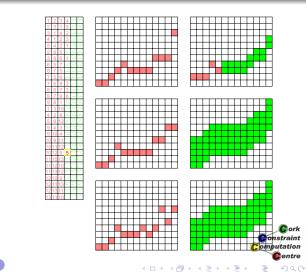
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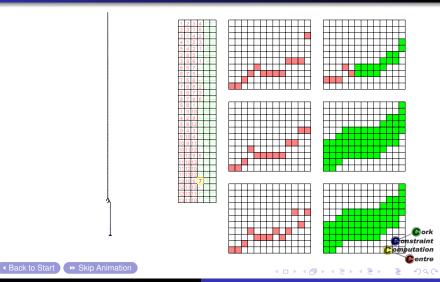


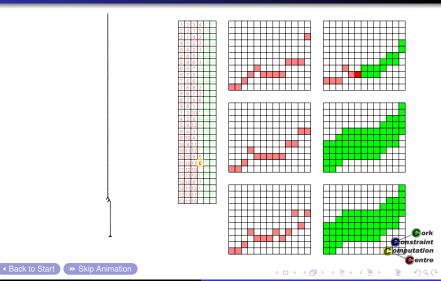


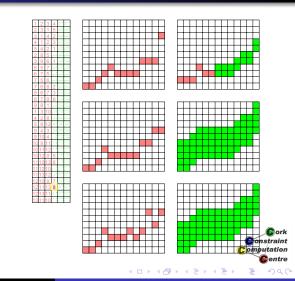






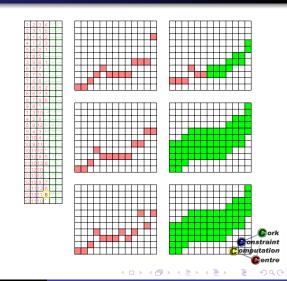




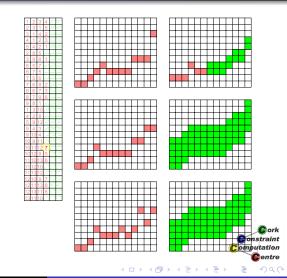


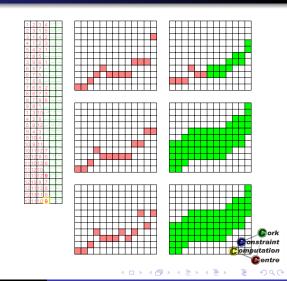


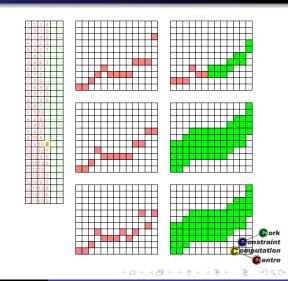


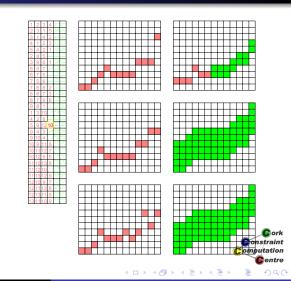






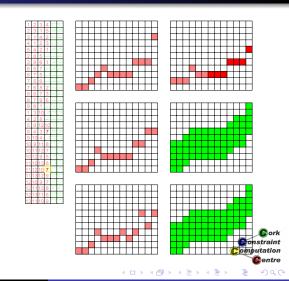


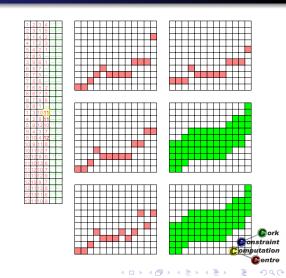


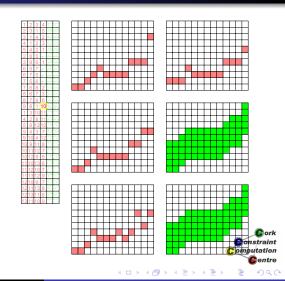




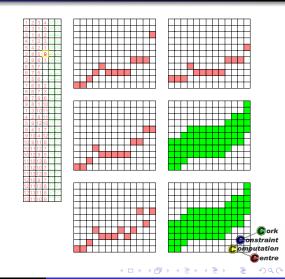


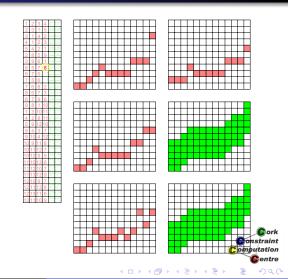


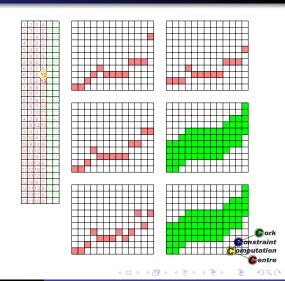


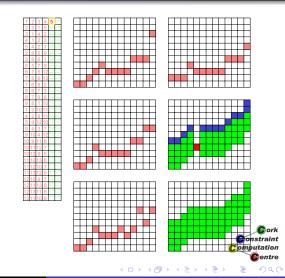


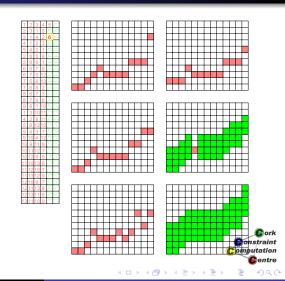




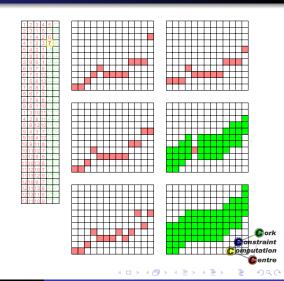




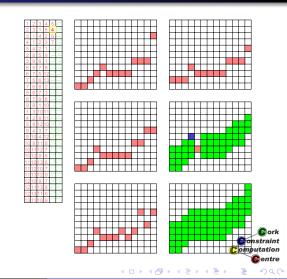




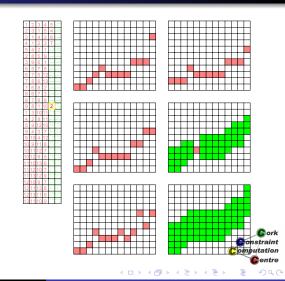




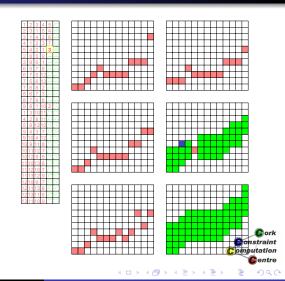




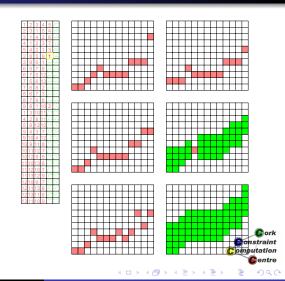




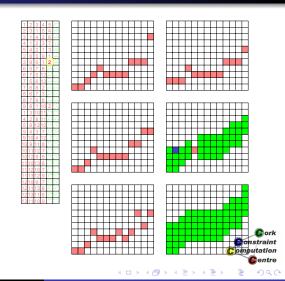


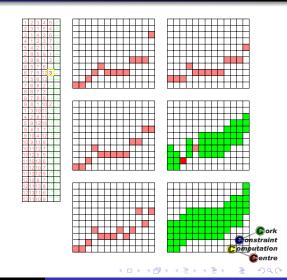




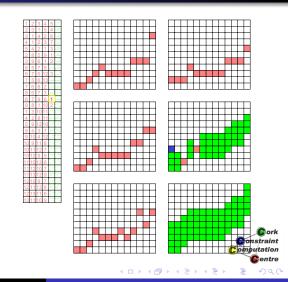




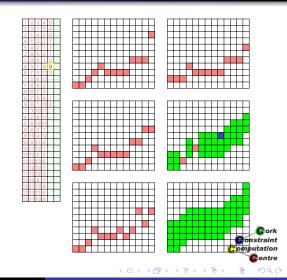




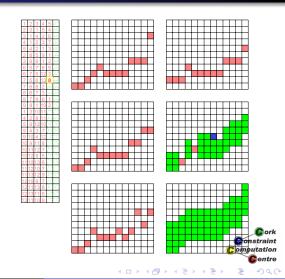




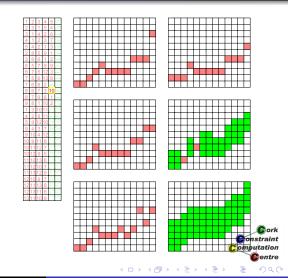


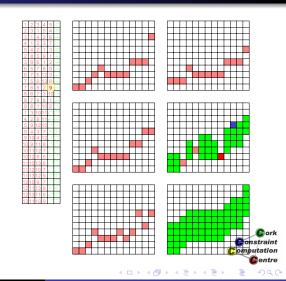




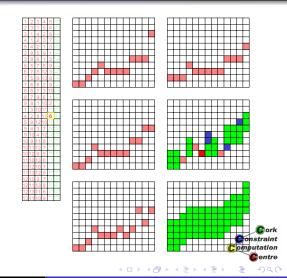


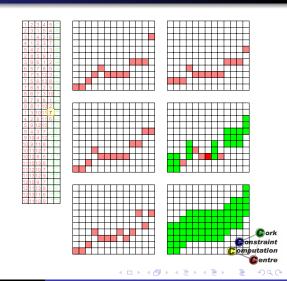


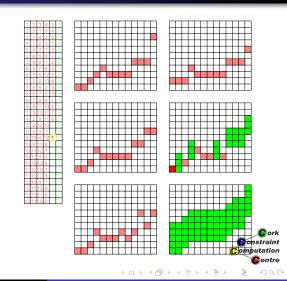


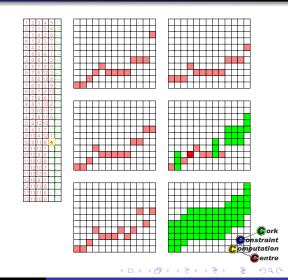




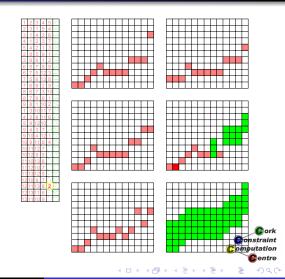


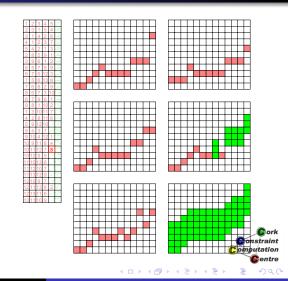




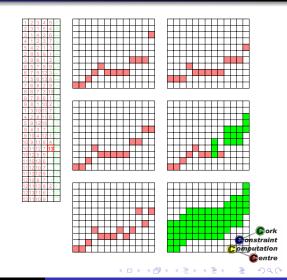




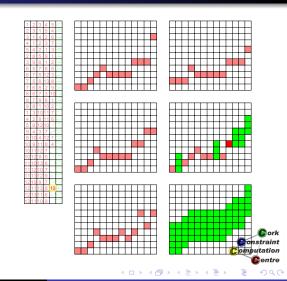




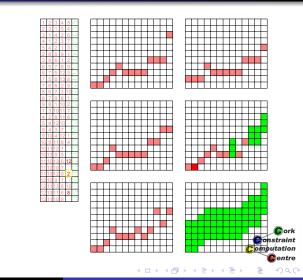






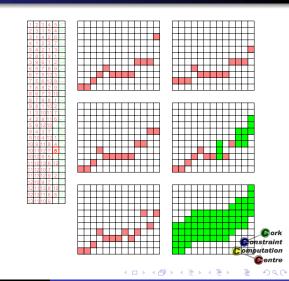




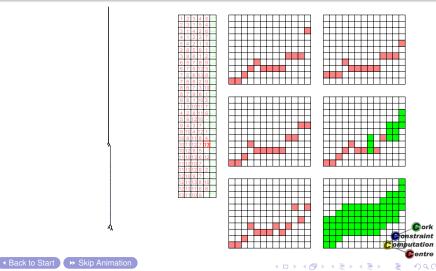


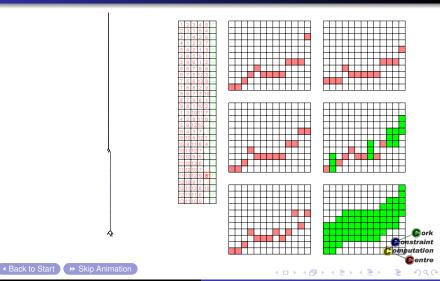


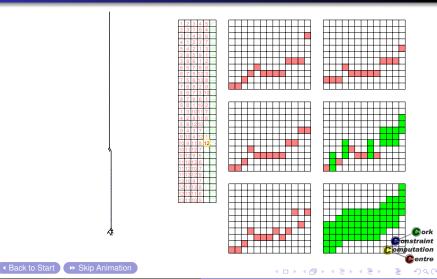


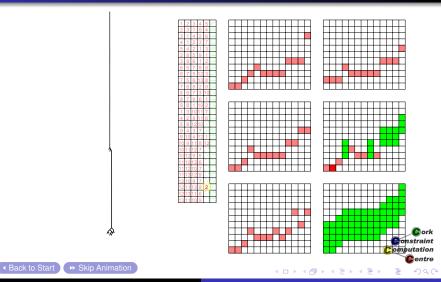


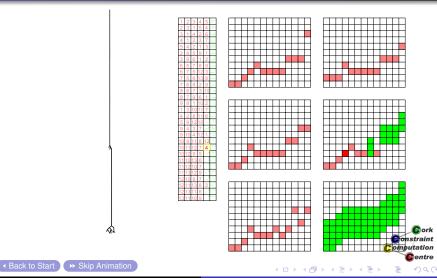


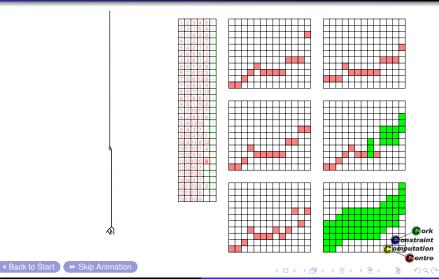


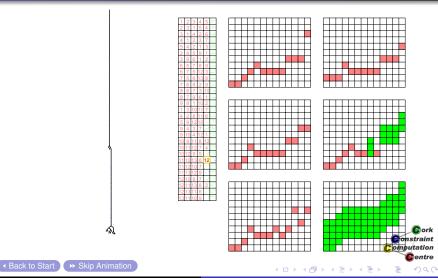


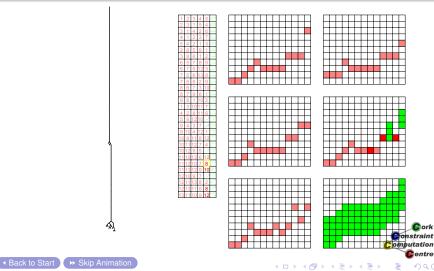


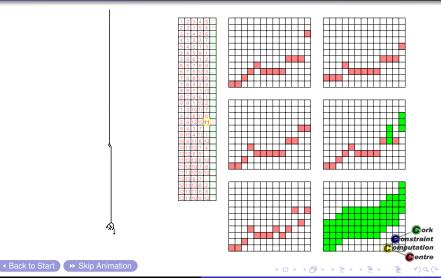


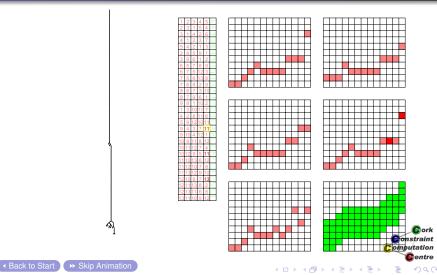


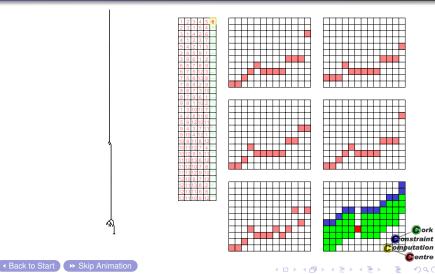


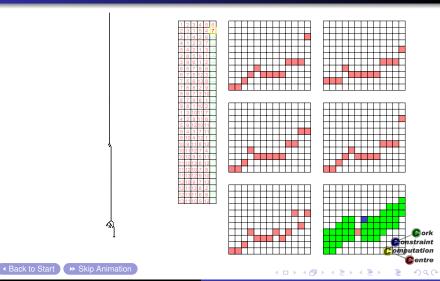


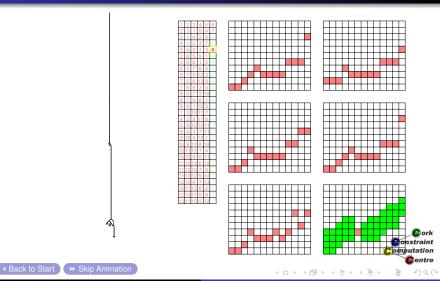


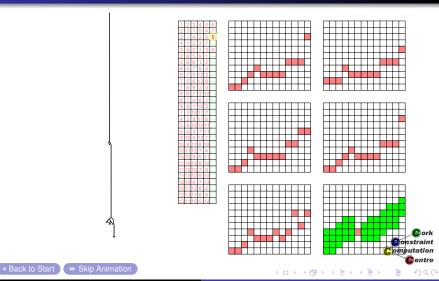


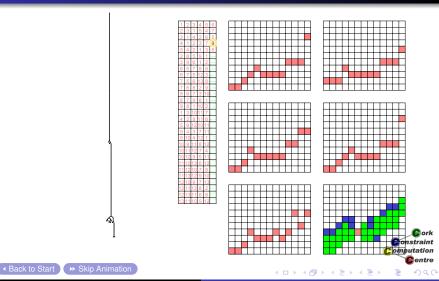


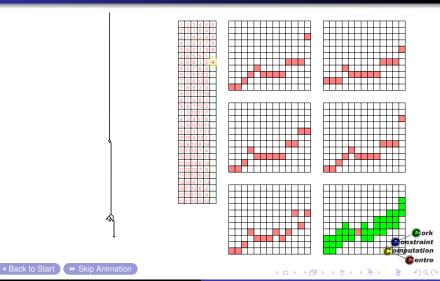


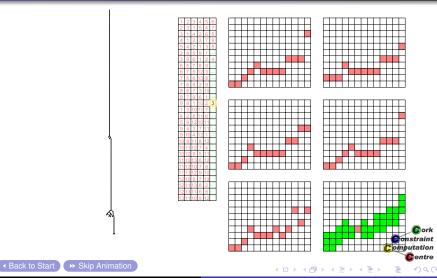


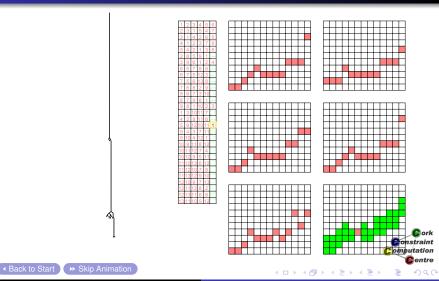


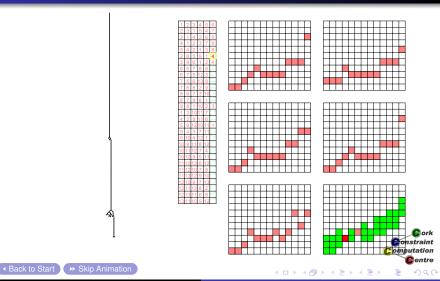


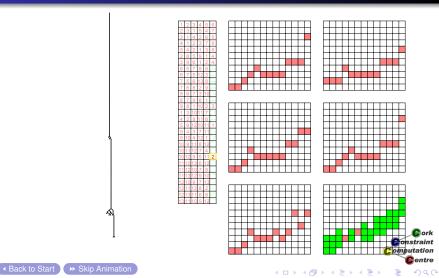


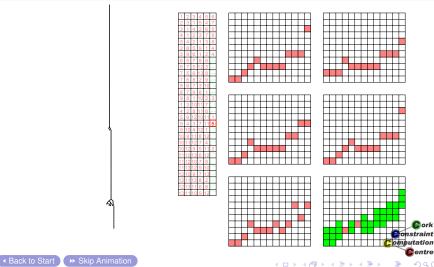


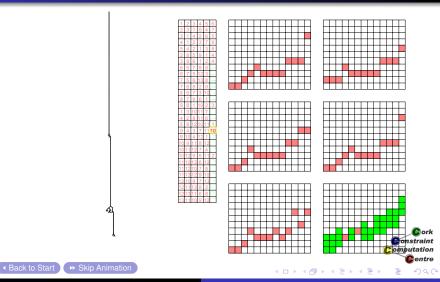


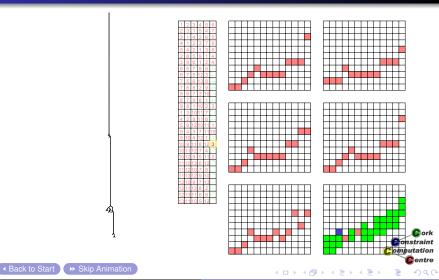


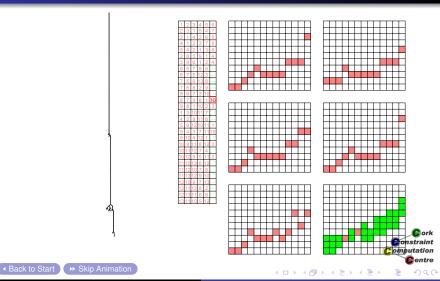


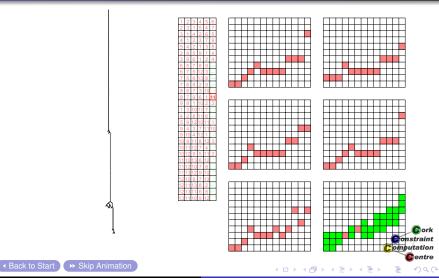


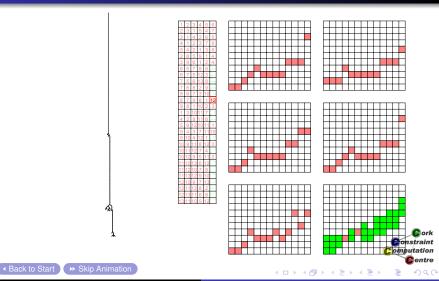


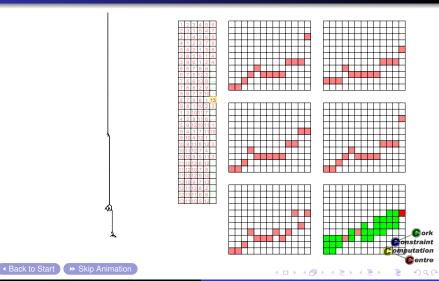


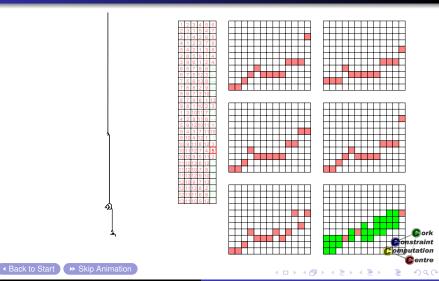


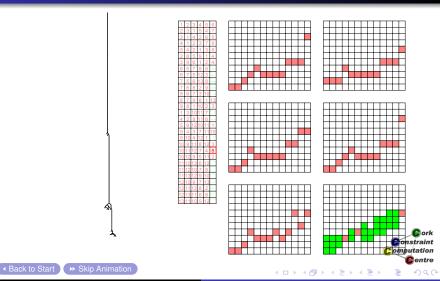


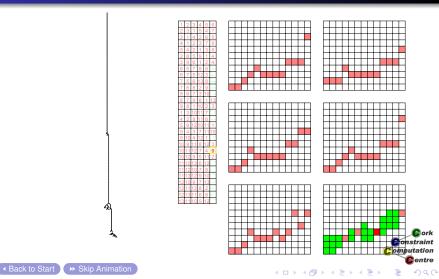


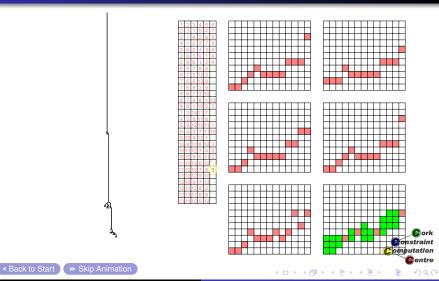


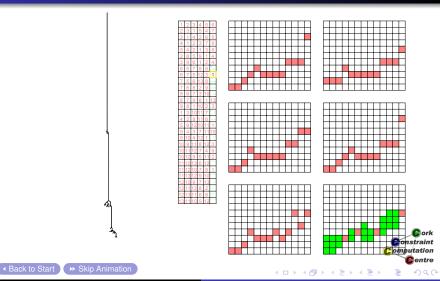


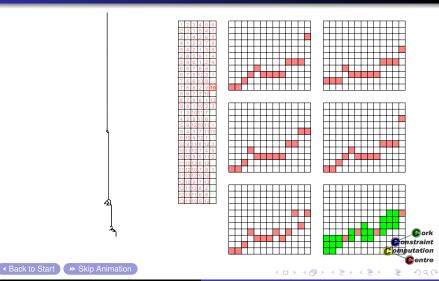


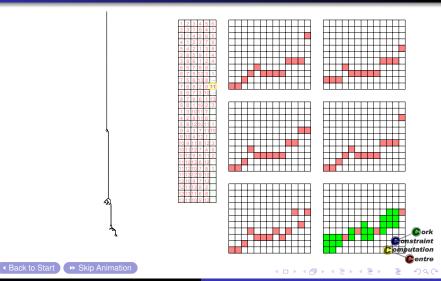


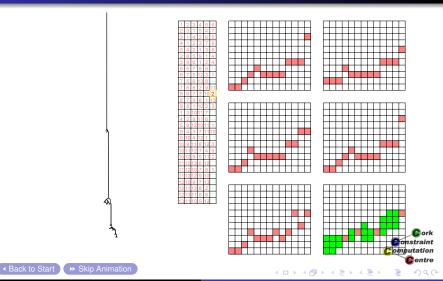


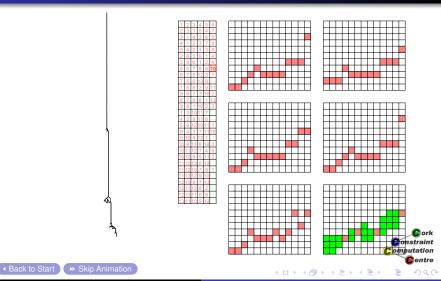


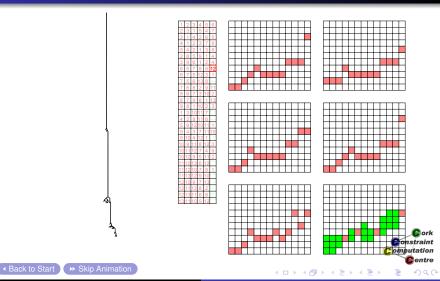


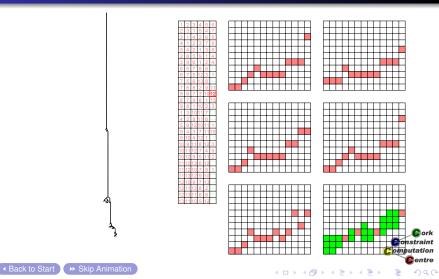


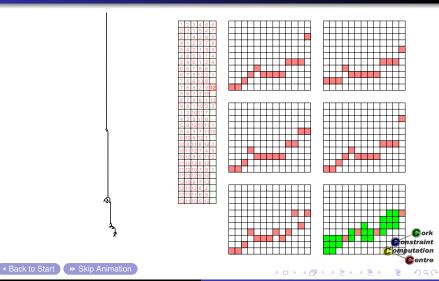


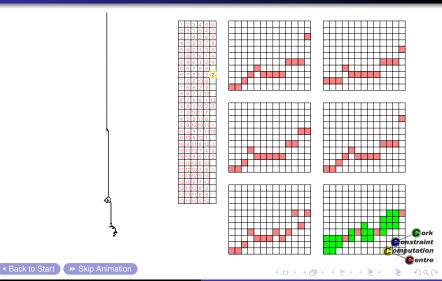


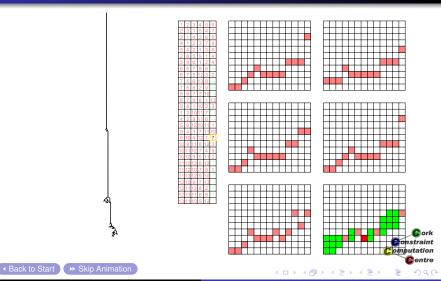


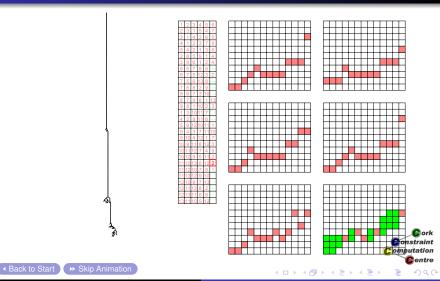


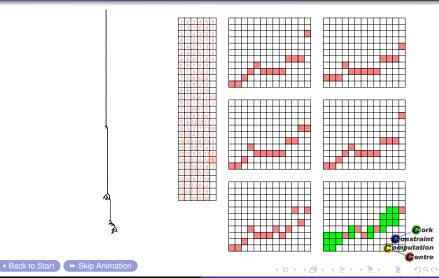


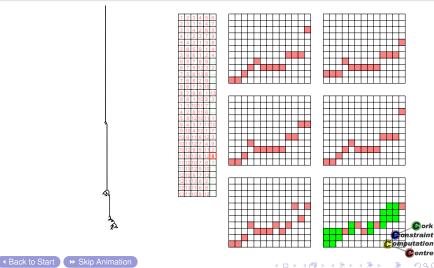


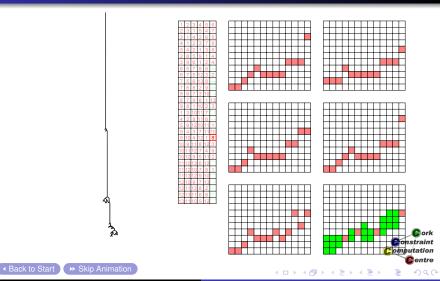


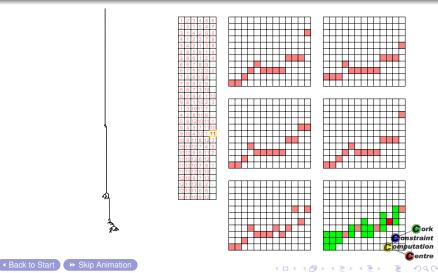


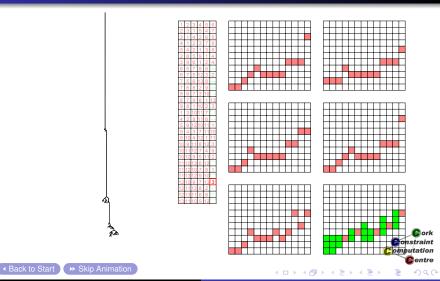


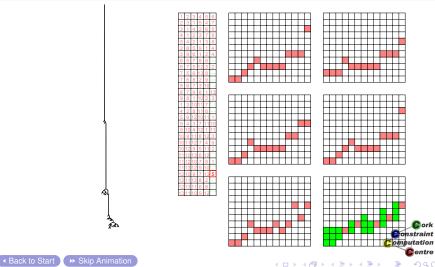


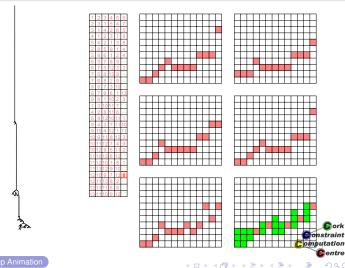


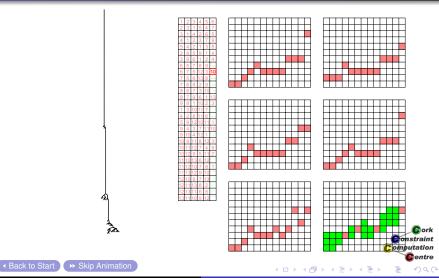


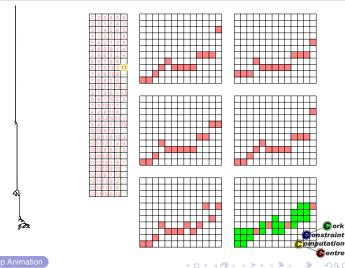




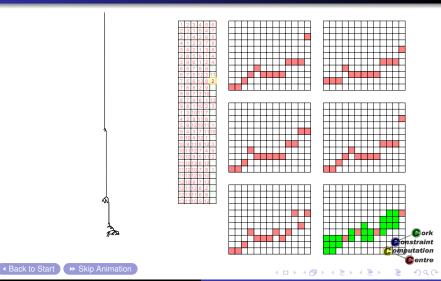


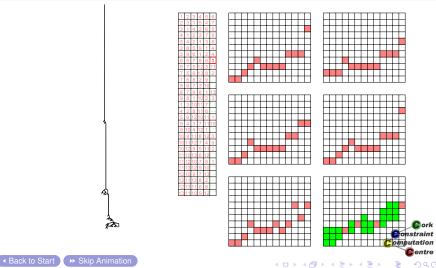


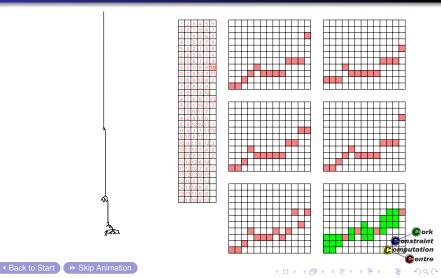


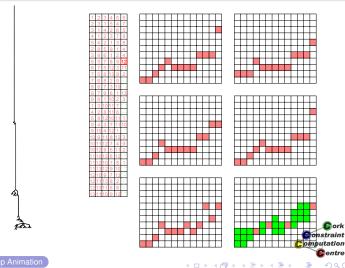


Customizing Search

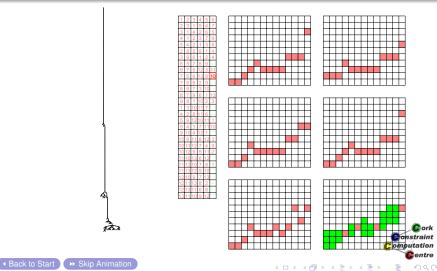


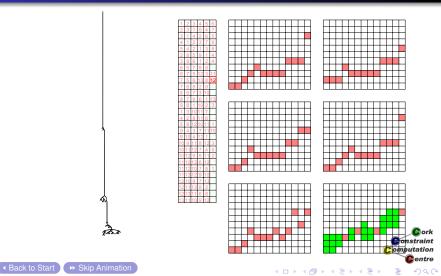


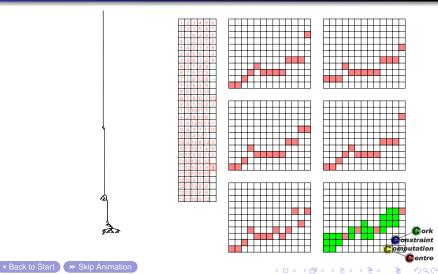


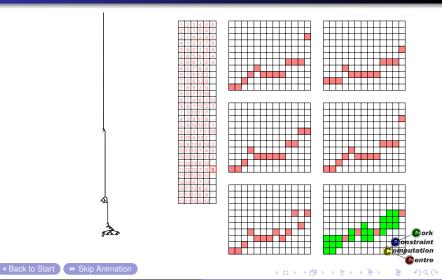


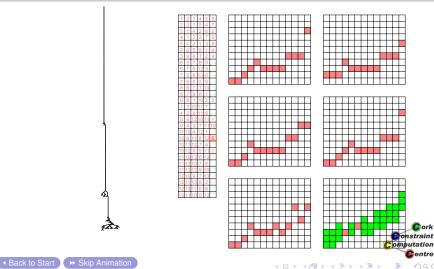


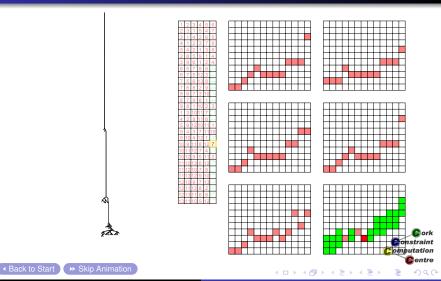


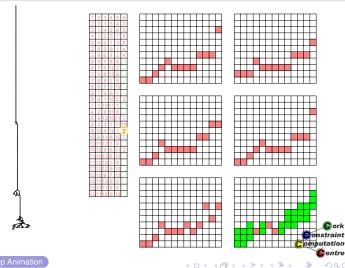




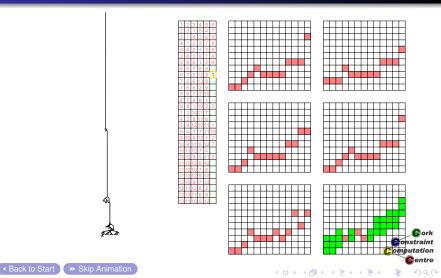


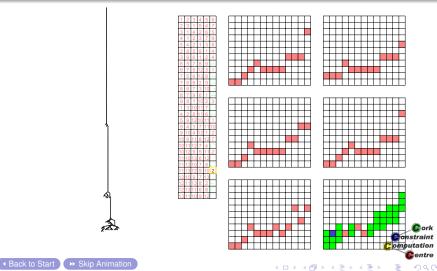


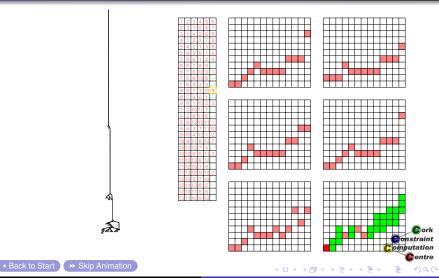


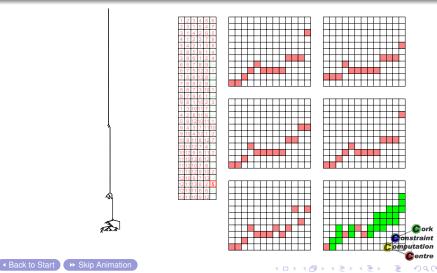


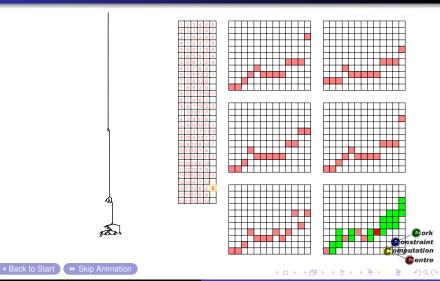


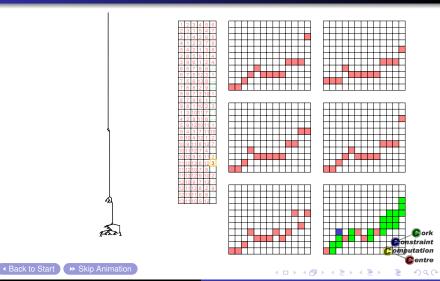


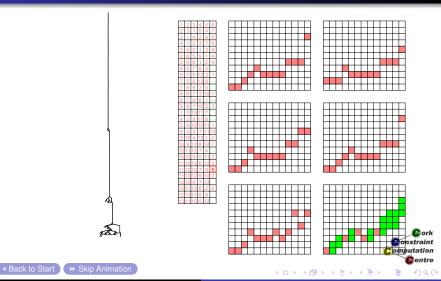


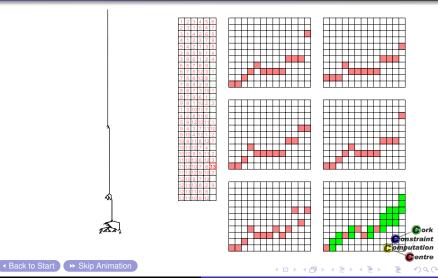


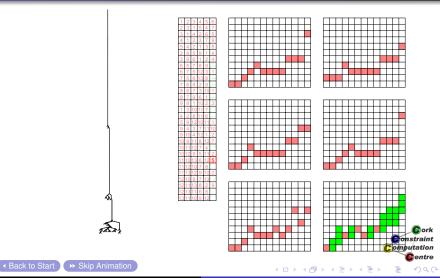


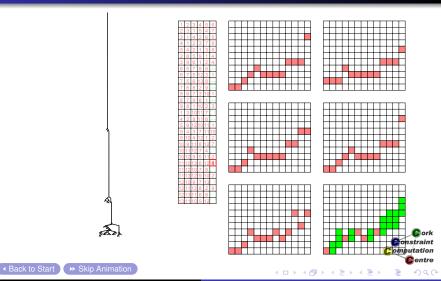


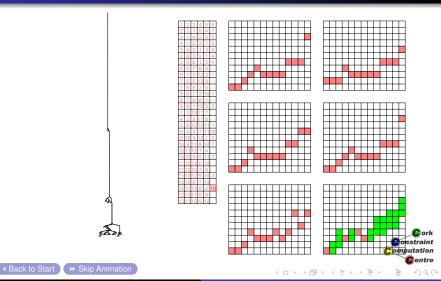


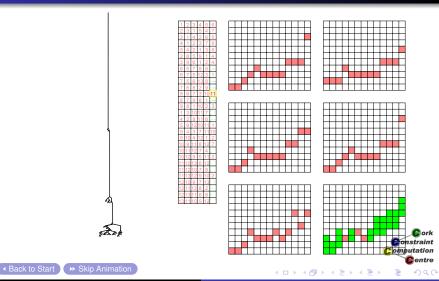


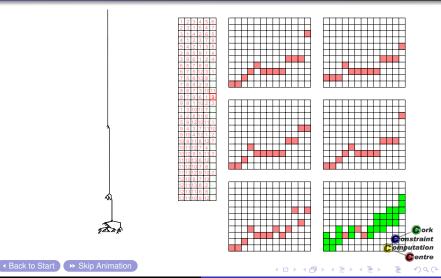


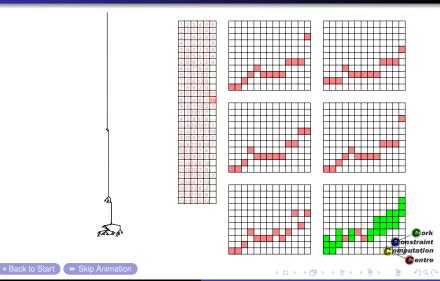


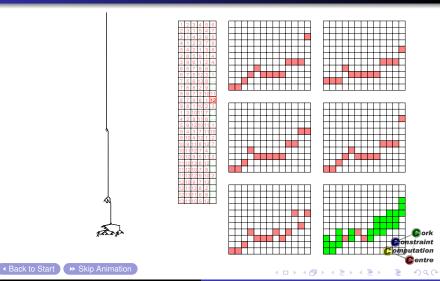


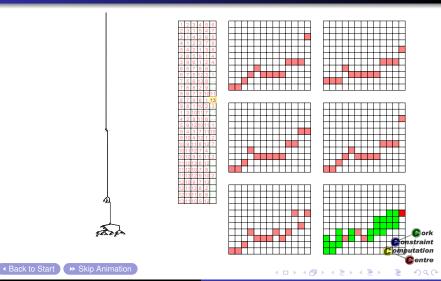


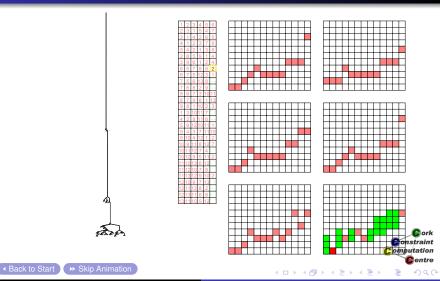


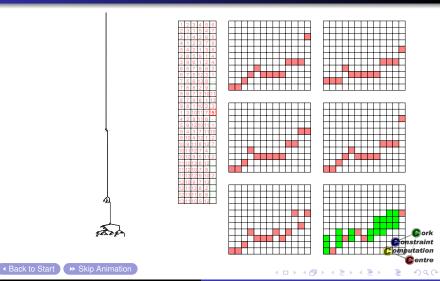


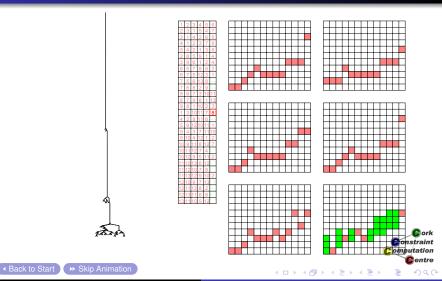


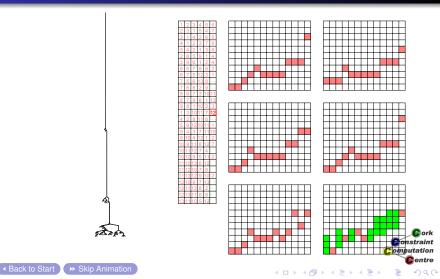


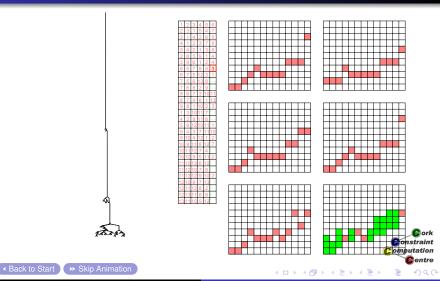


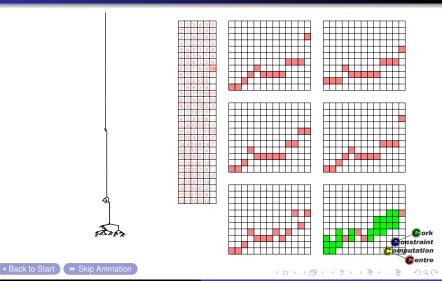


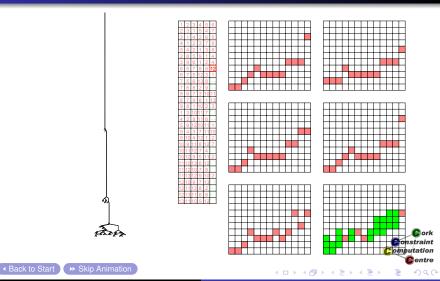


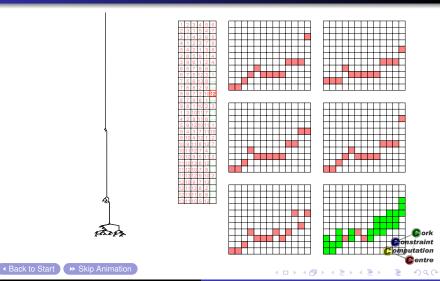


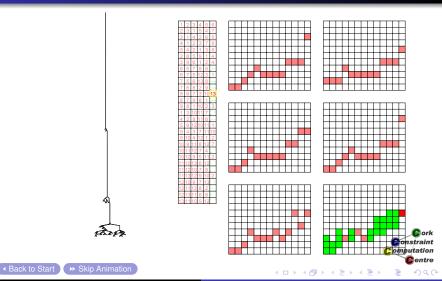


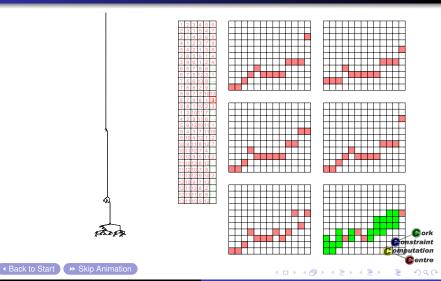


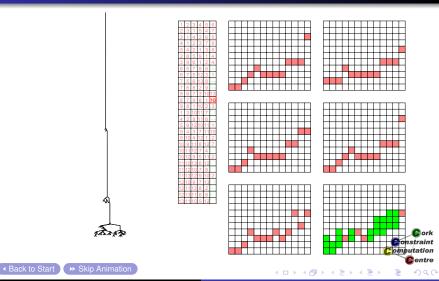


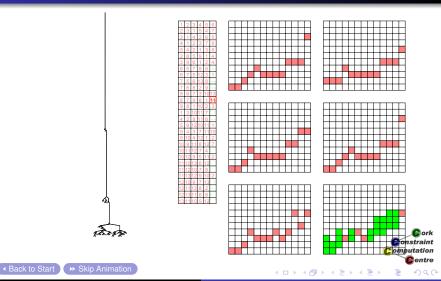


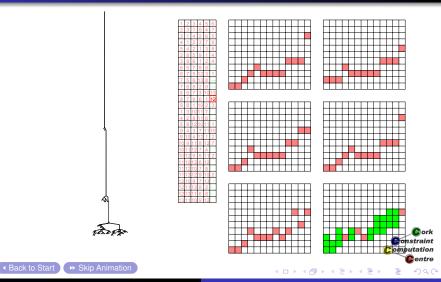


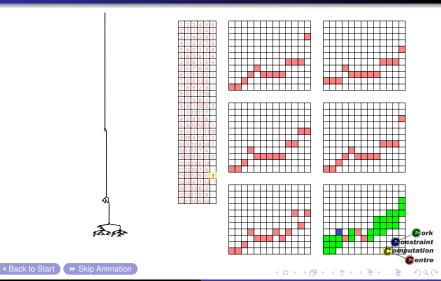


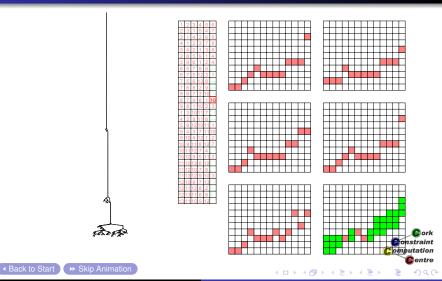


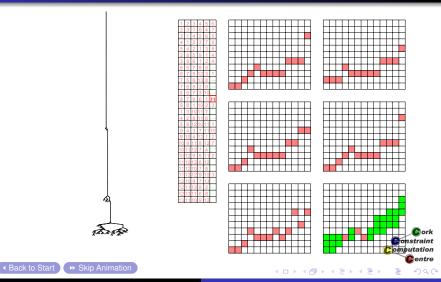


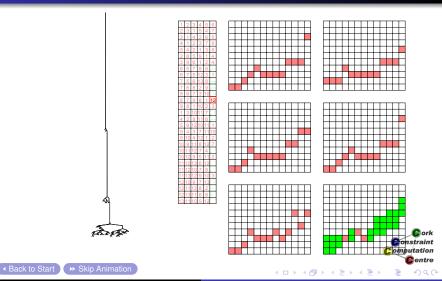


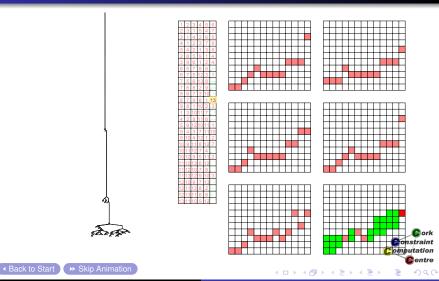


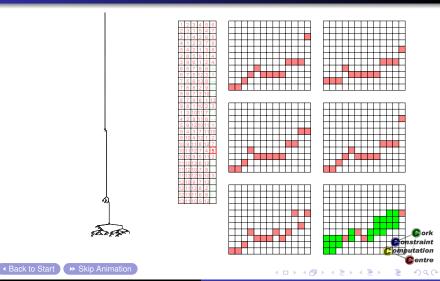


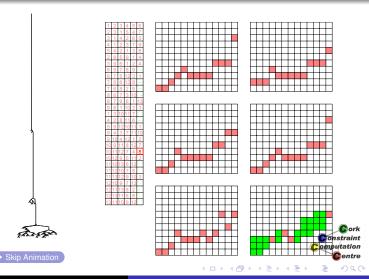


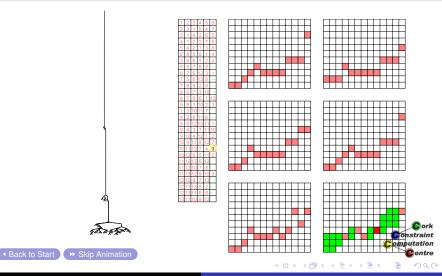


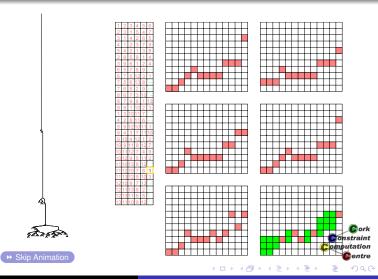


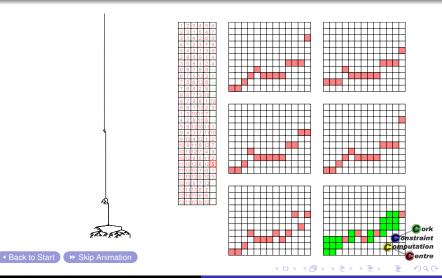


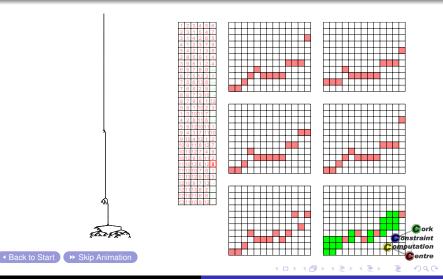


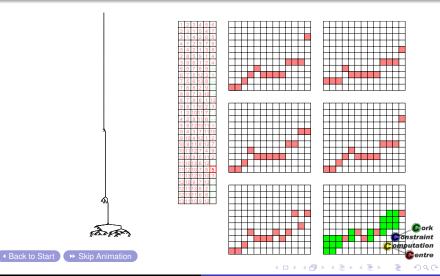


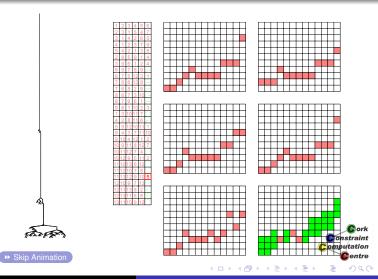


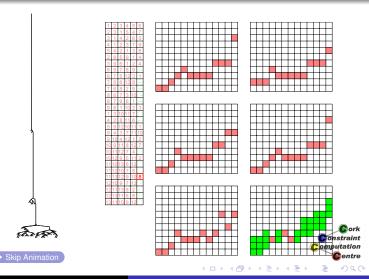


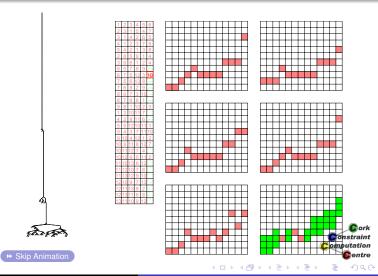


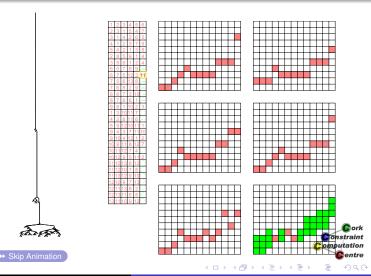


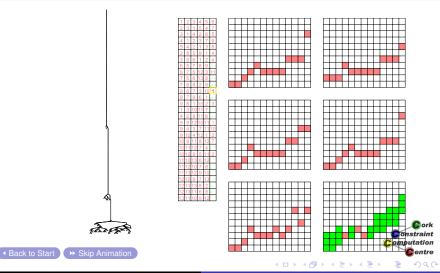


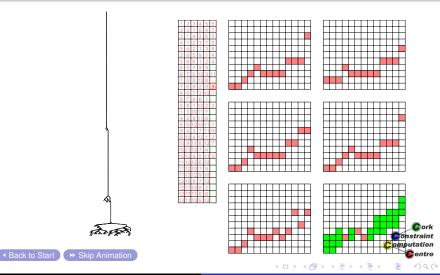


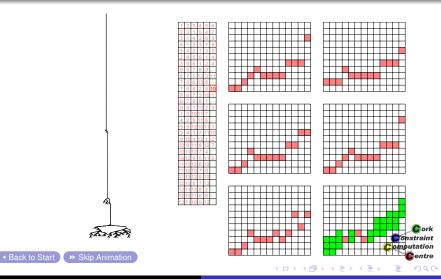


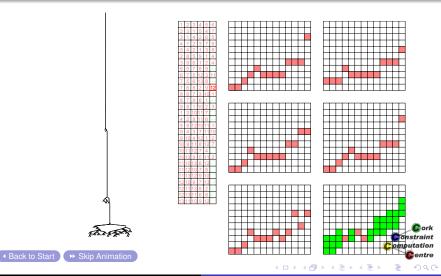


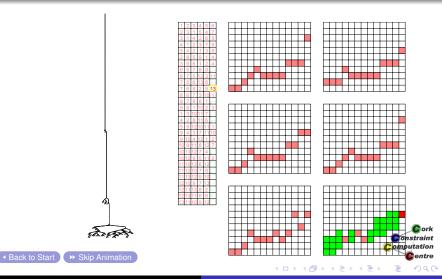


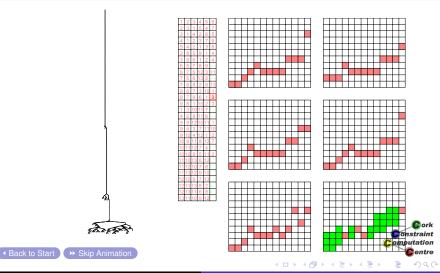


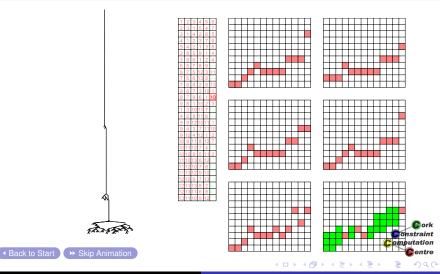


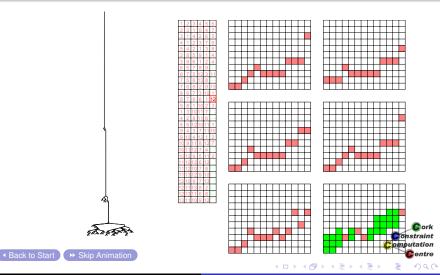


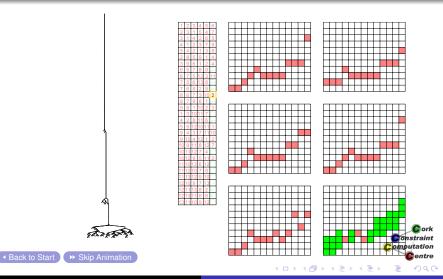


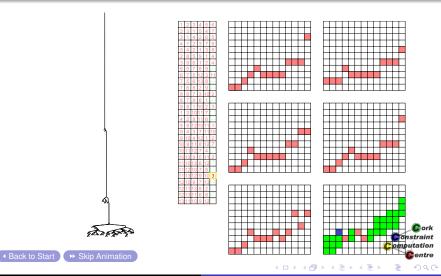


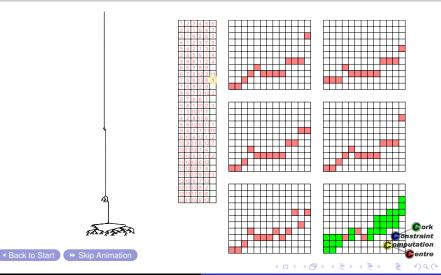


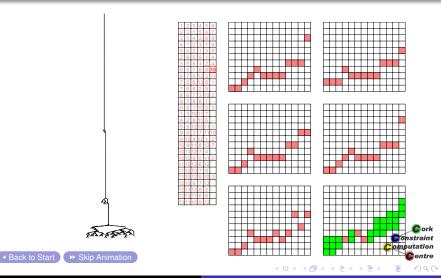


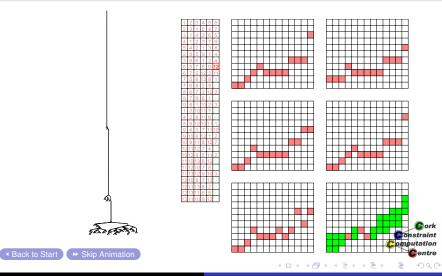


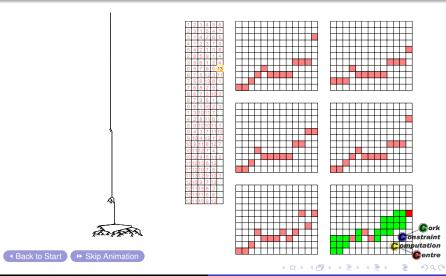


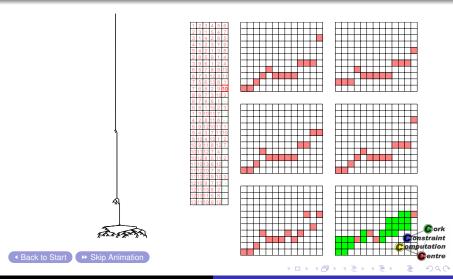


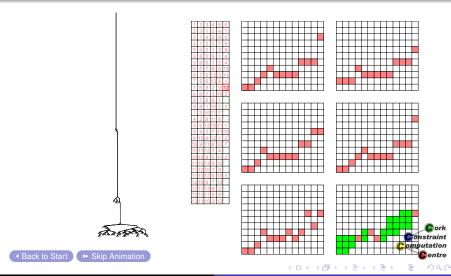


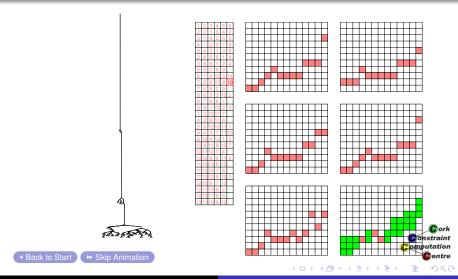


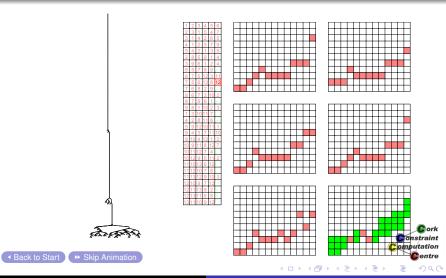


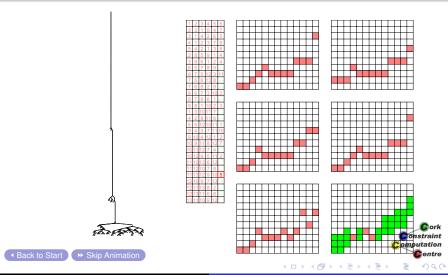


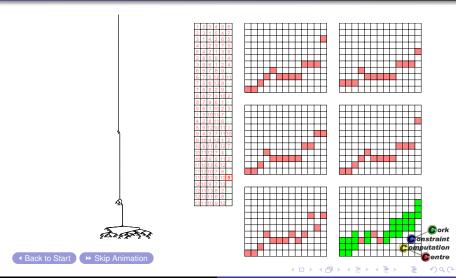


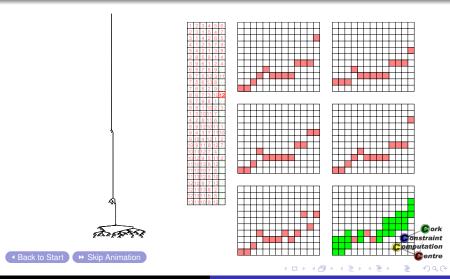


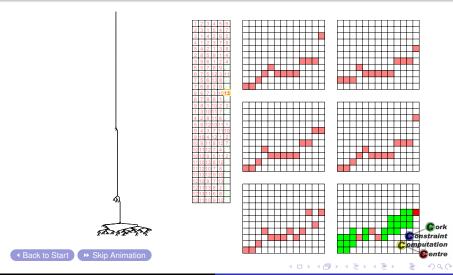


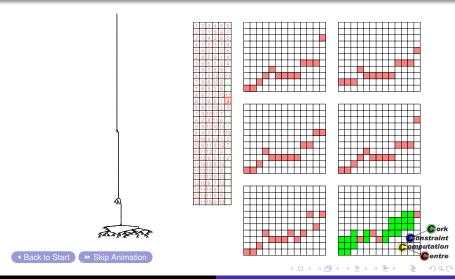


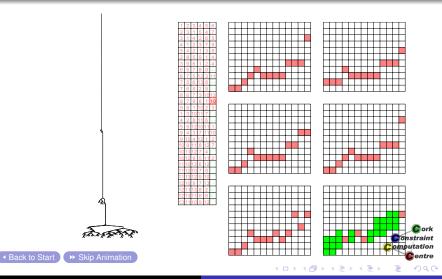


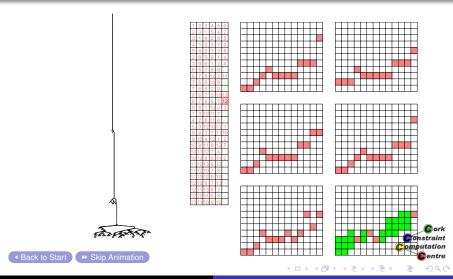


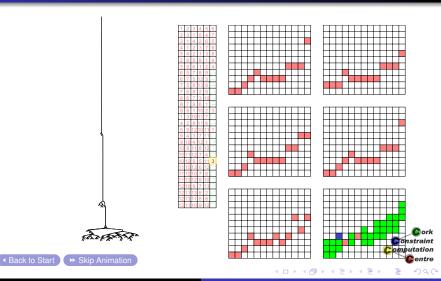


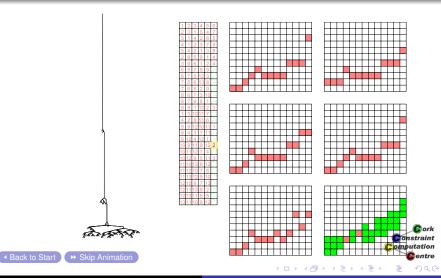


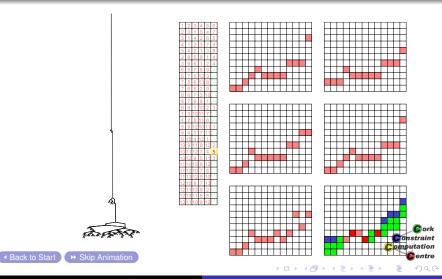


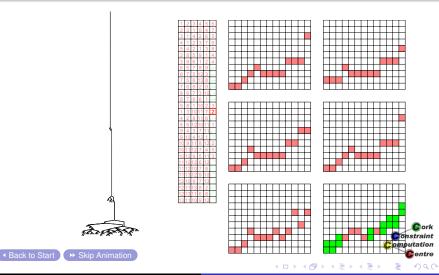


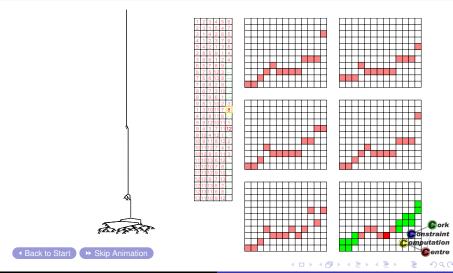


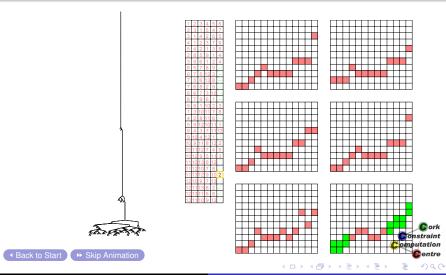


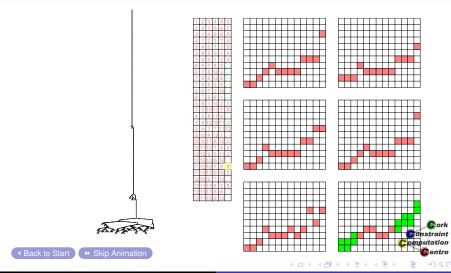


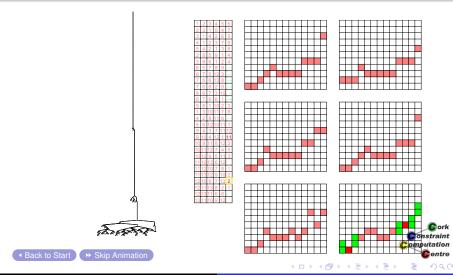


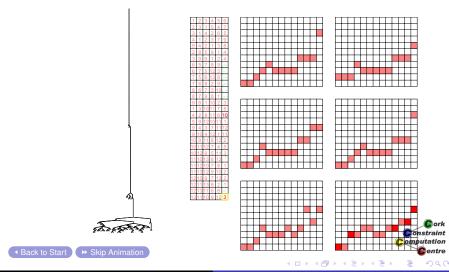


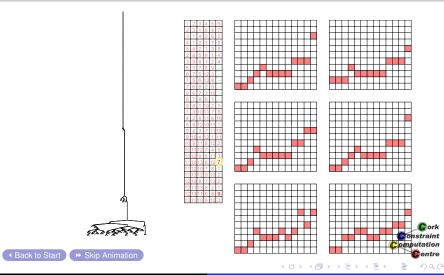


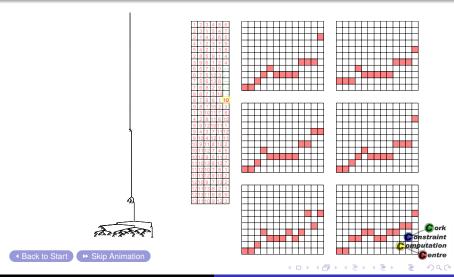


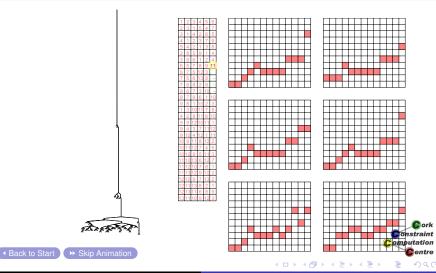


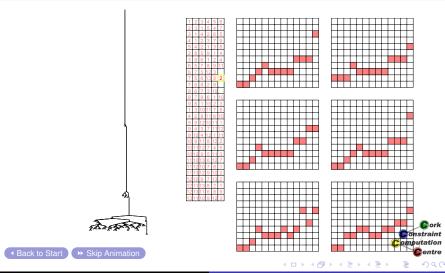


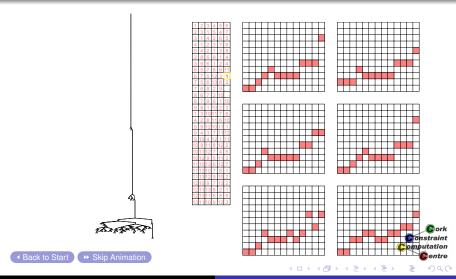


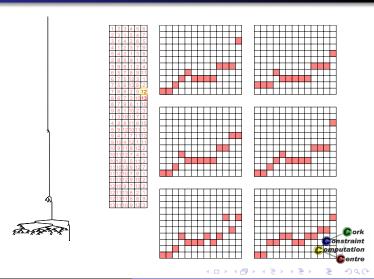




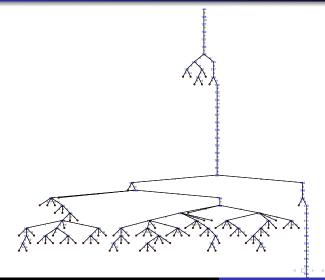








Layered with Credit Search (Zoomed)





Observations

- Improved search
- Need more sample problems to really understand impact





Idea

- Randomize value selection
- Remove bias picking bins in same order
- Allows to add restart
- When spending too much time without finding solution
- Restart search from beginning
- Randomization will explore other initial assignments
- Do not get caught in "dead" part of search tree

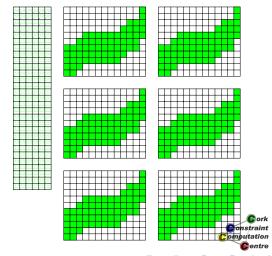


Randomized with Restart

```
assign (Matrix, NrPeriods, NrGuests):-
    repeat,
    (for (J, 1, NrPeriods),
     param (Matrix, NrGuests) do
         NSq is NrGuests*NrGuests,
         once (search (Matrix[1..NrGuests, J], 0,
                      first_fail, indomain_random,
                      credit (NSq, 10), []))
```

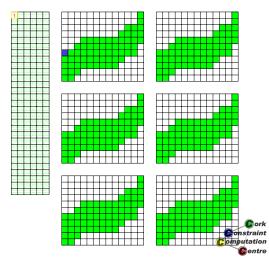
Layered Search
Layered with Credit Search
Randomized with Restart



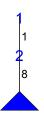


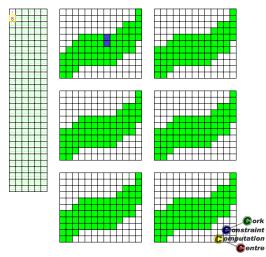
Randomized with Restart

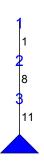


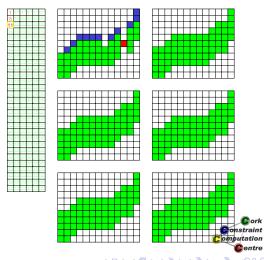


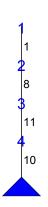
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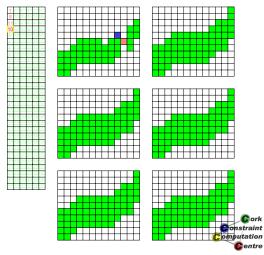




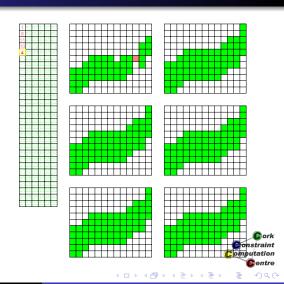




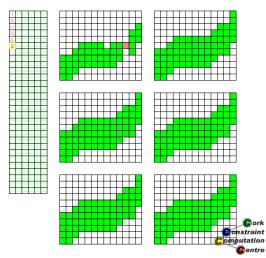




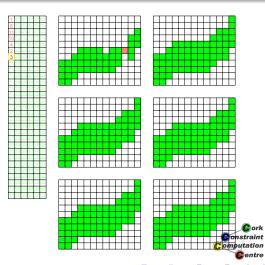




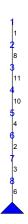


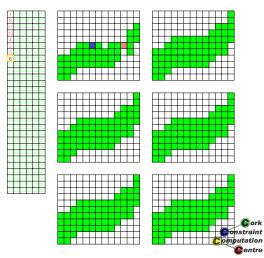




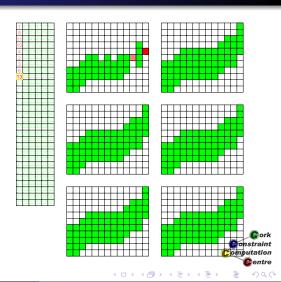




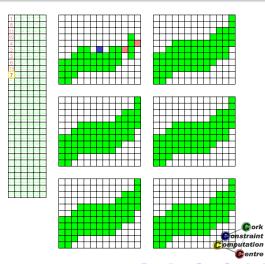




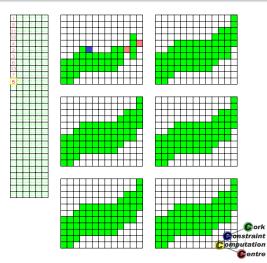




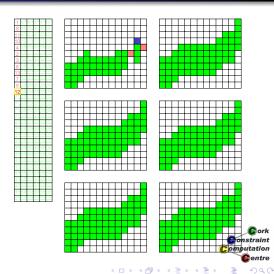




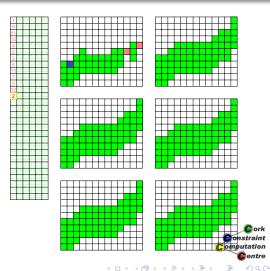




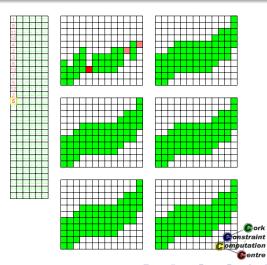






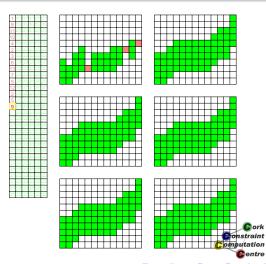






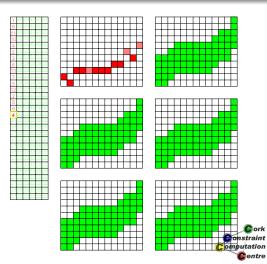




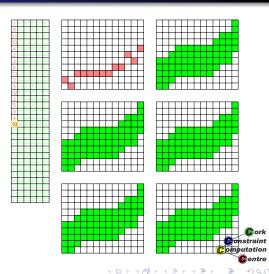






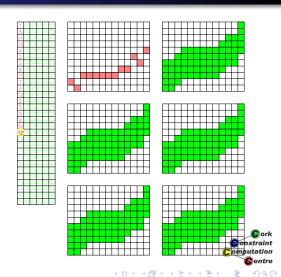








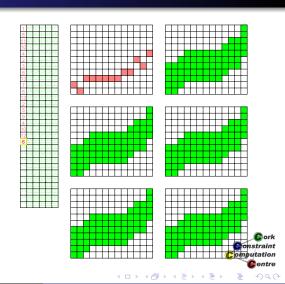




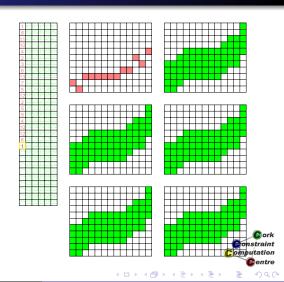


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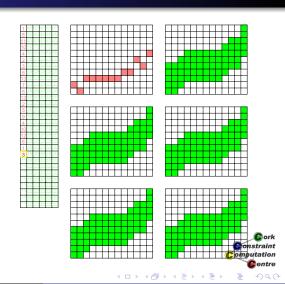




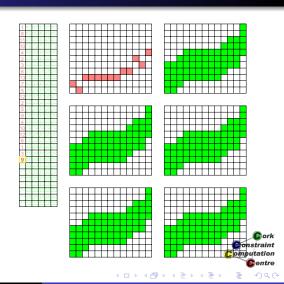


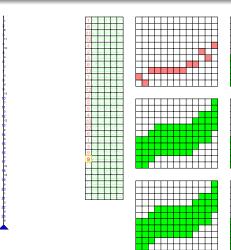






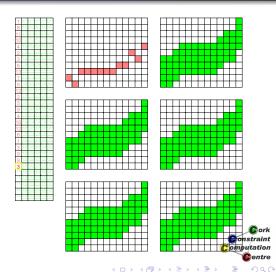


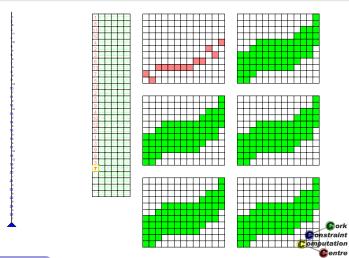


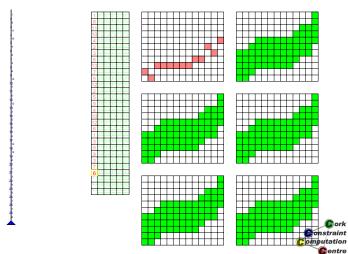


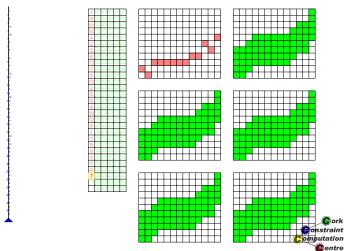
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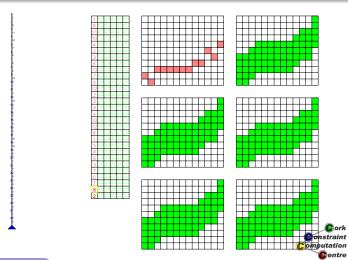


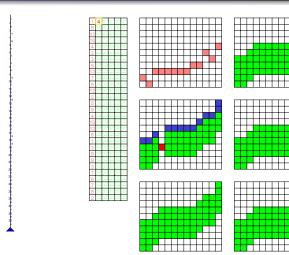




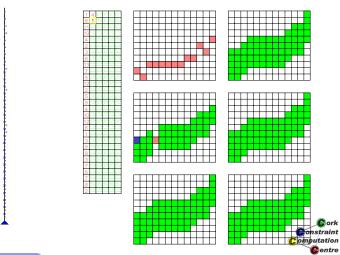


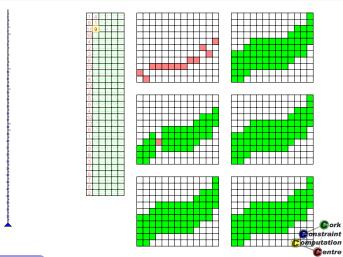


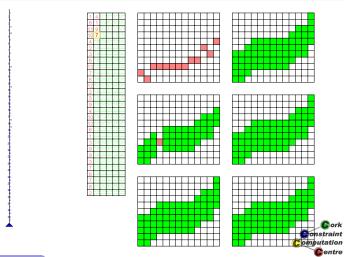




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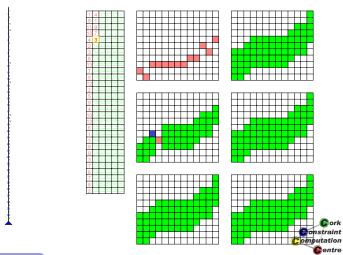


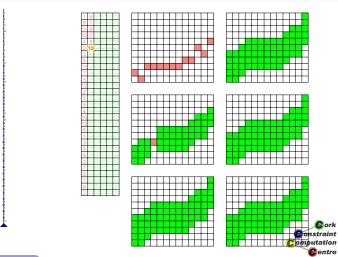


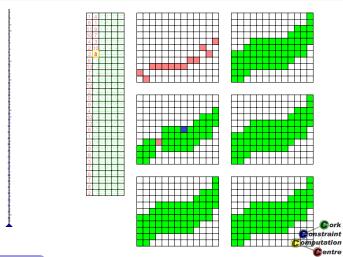


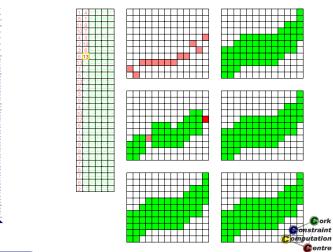
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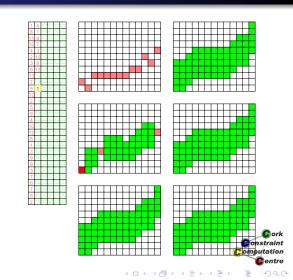
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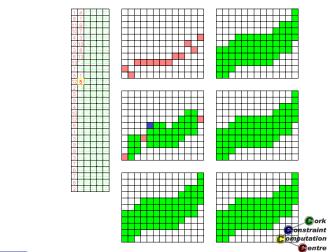


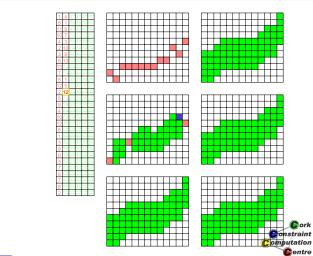


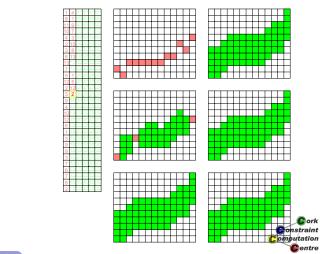


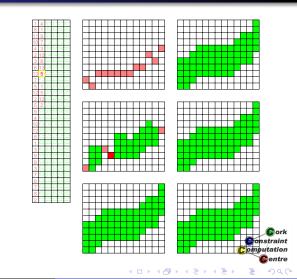


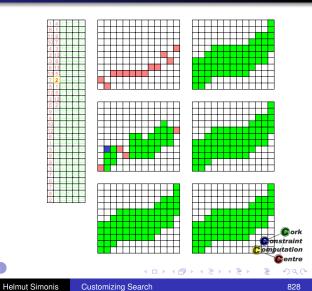


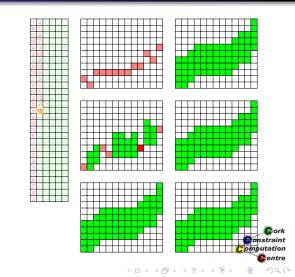


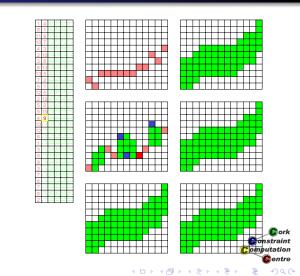


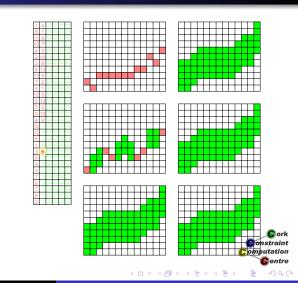






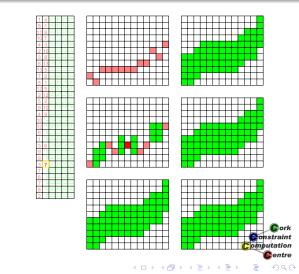




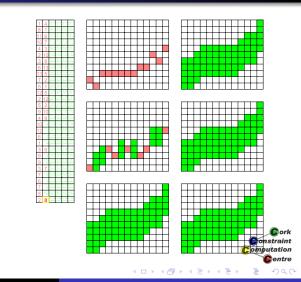


◆ Back to Start

◆ Skip Animation

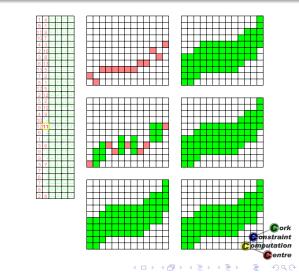


Layered Search
Layered with Credit Search
Randomized with Restart

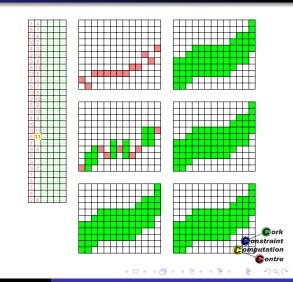


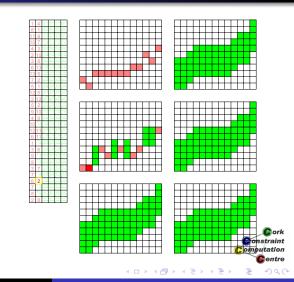
◆ Back to Start

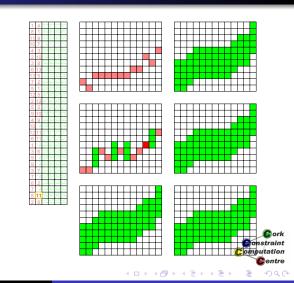
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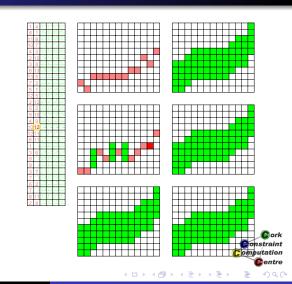


Layered Search
Layered with Credit Search
Randomized with Restart

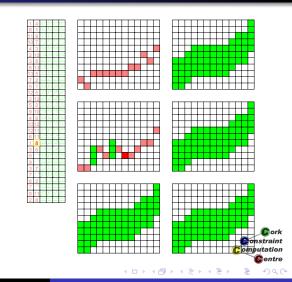


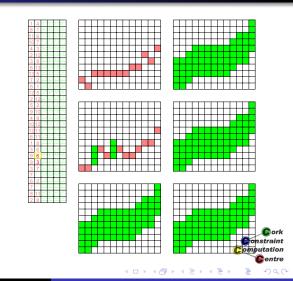


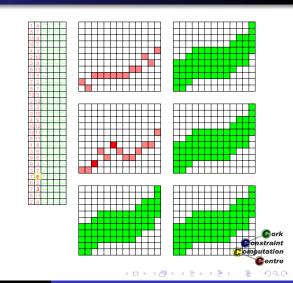


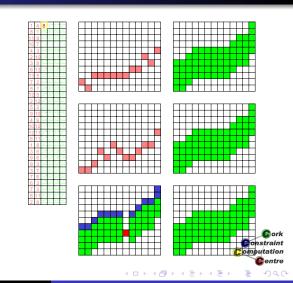


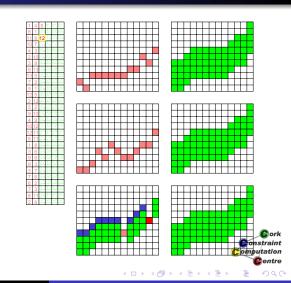


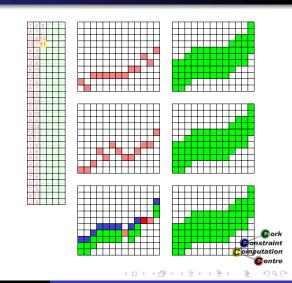


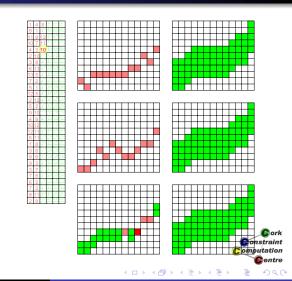


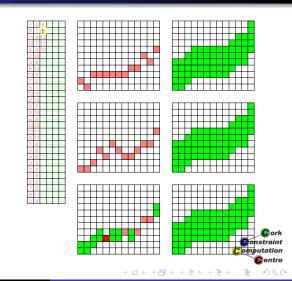


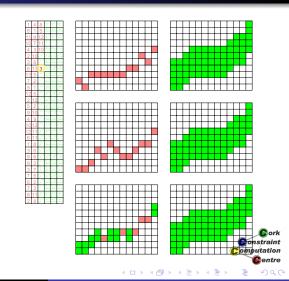


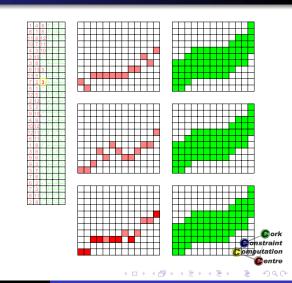


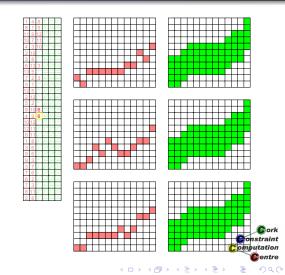


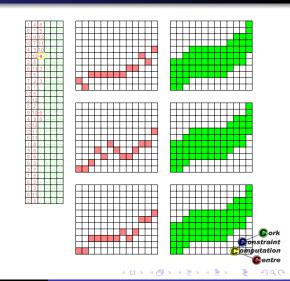


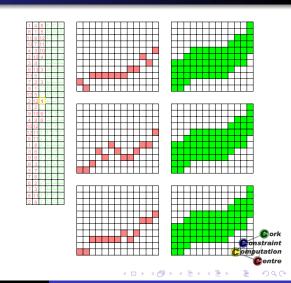




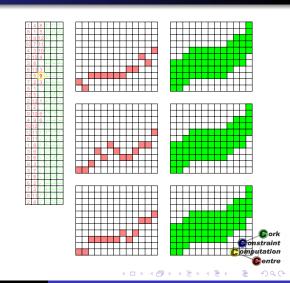


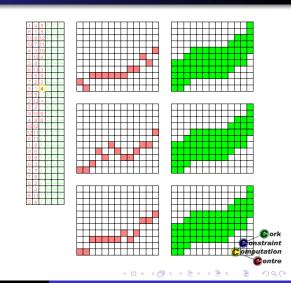


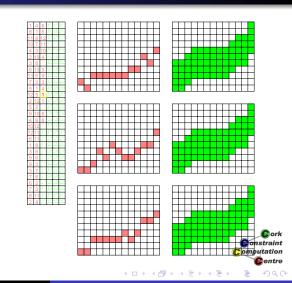




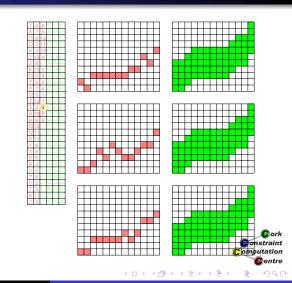


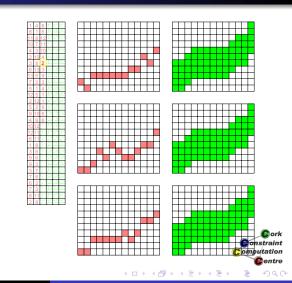


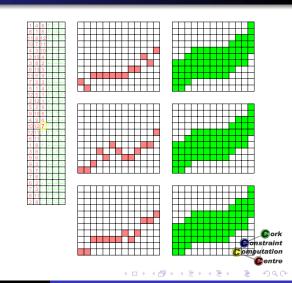


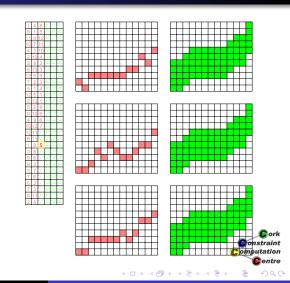


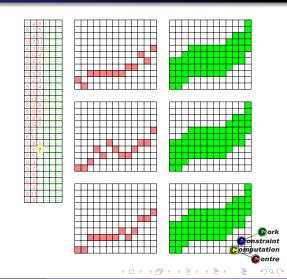


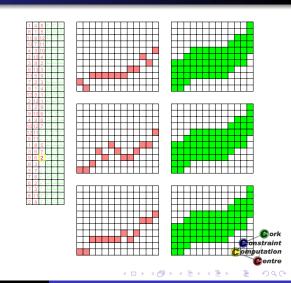




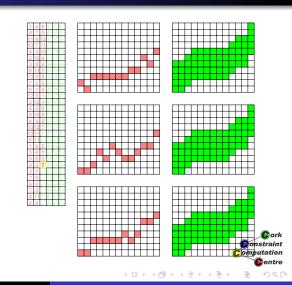




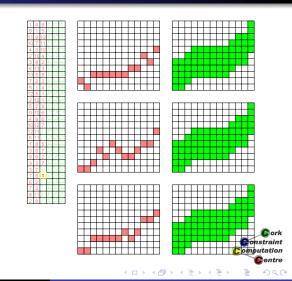


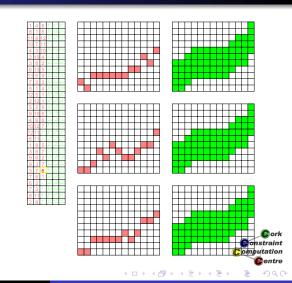


Randomized with Restart

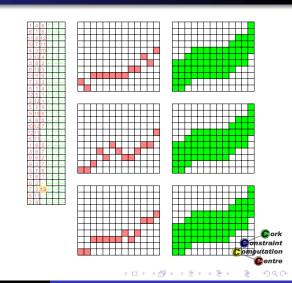


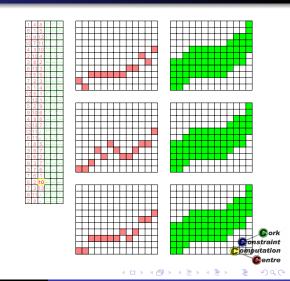




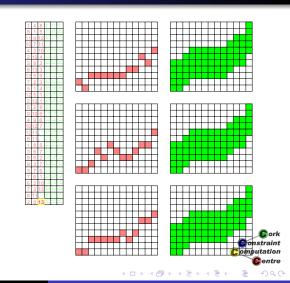


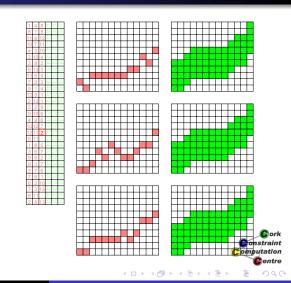
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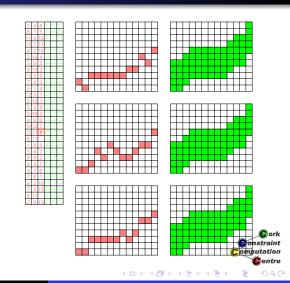




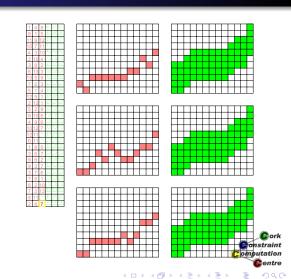
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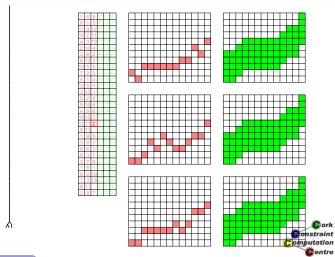




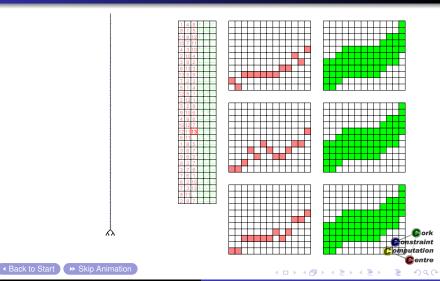


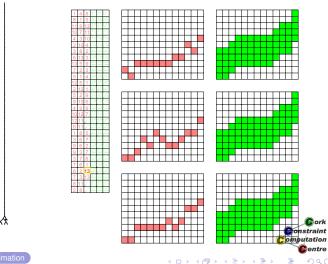


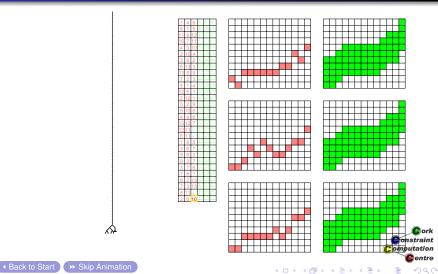


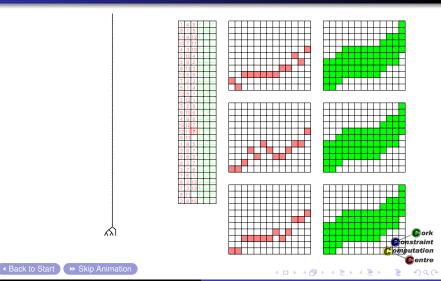


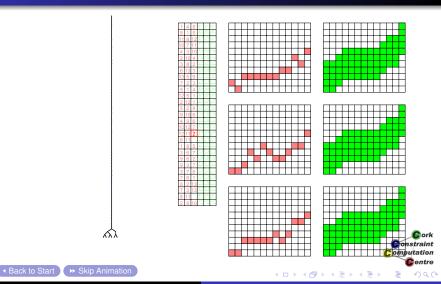
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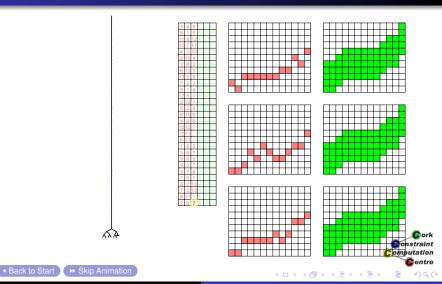


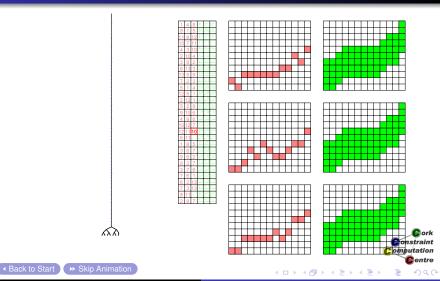


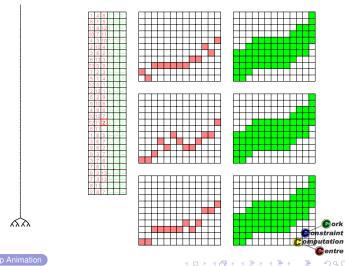


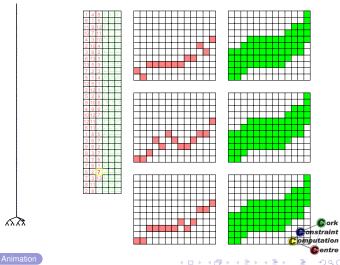


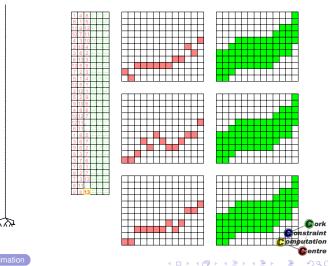




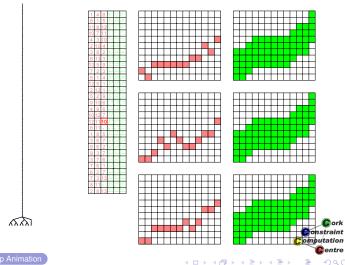


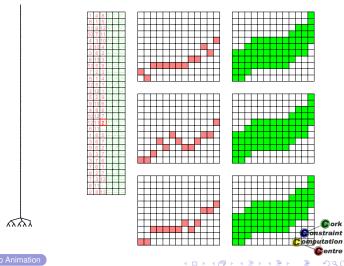




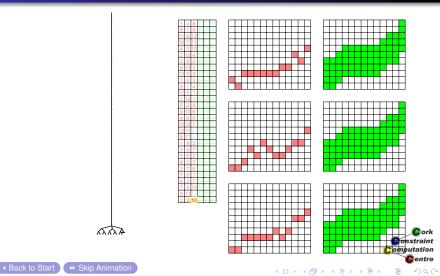


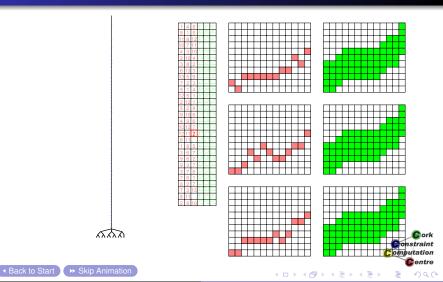


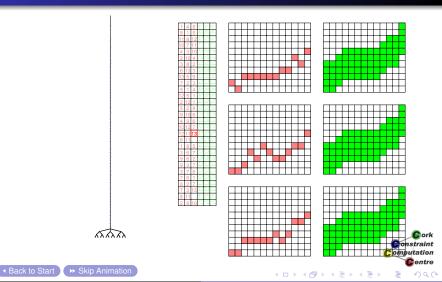


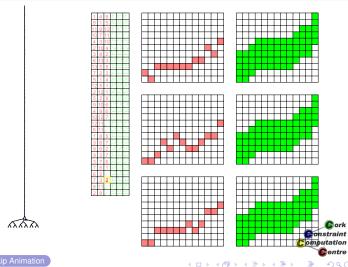






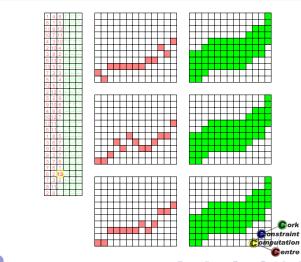


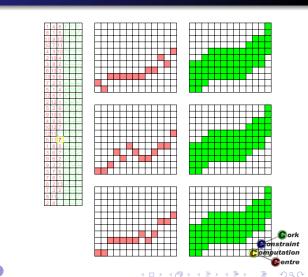




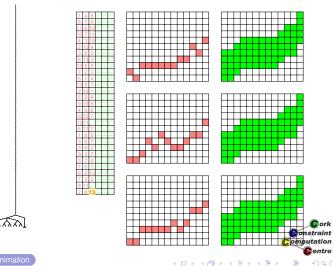


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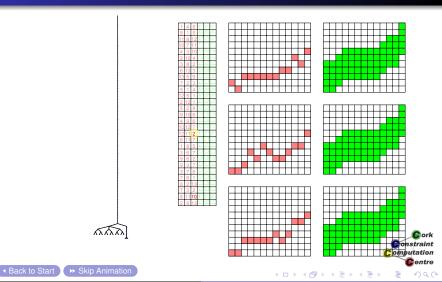


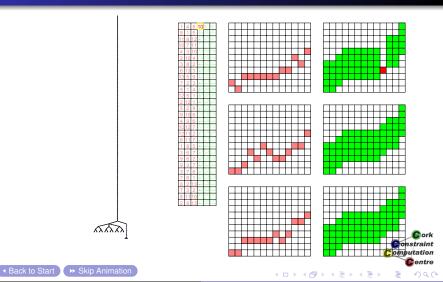


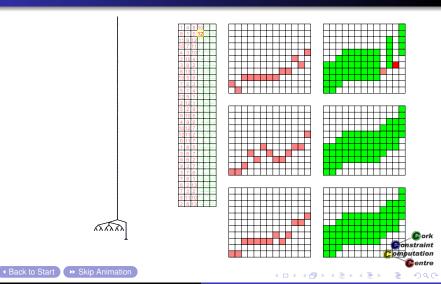
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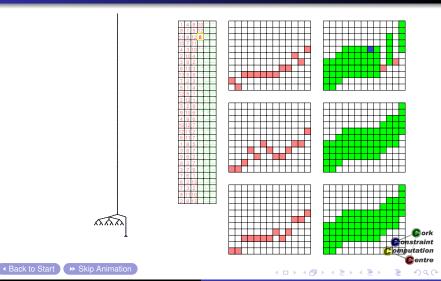


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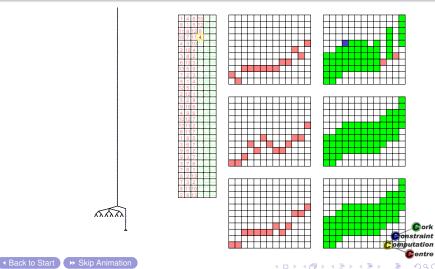




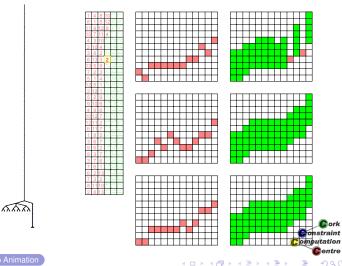




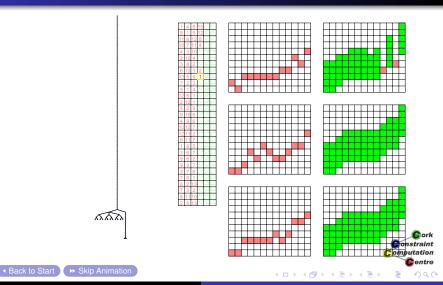
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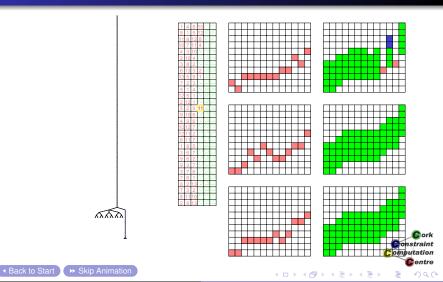


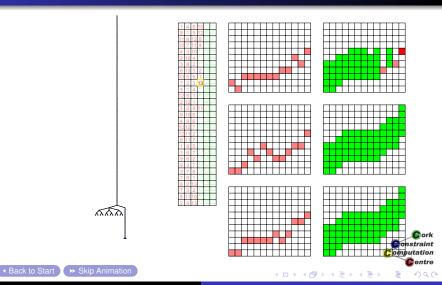
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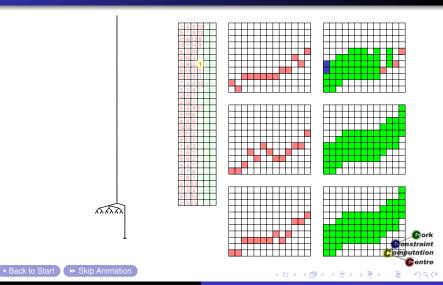


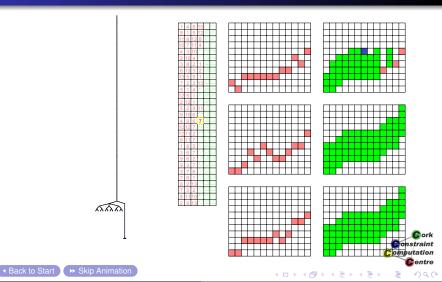
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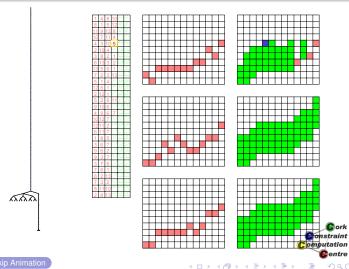


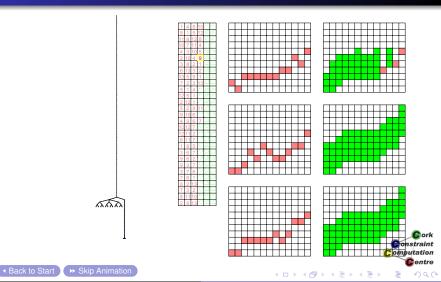


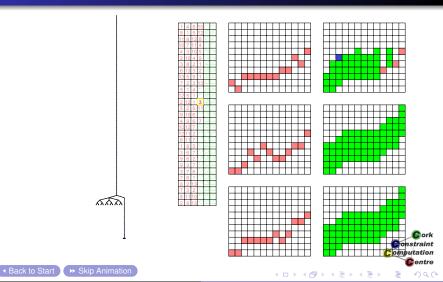


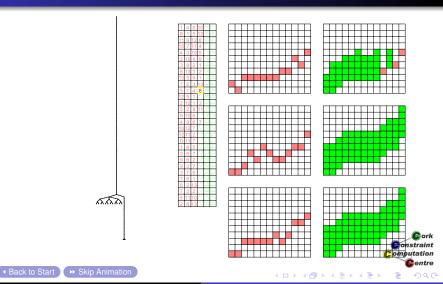


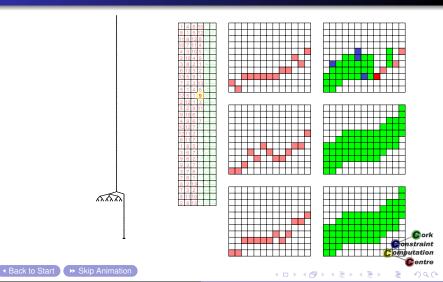


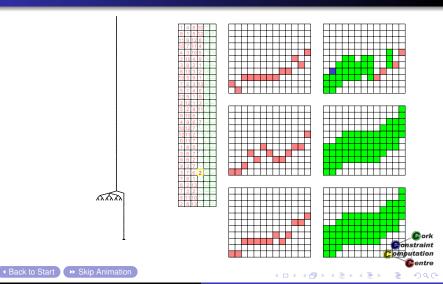


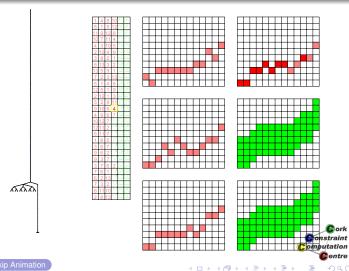




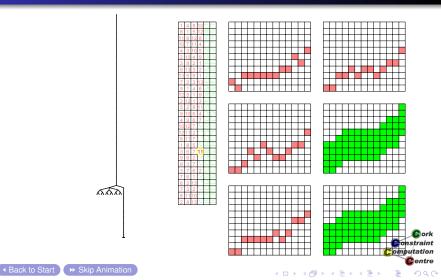


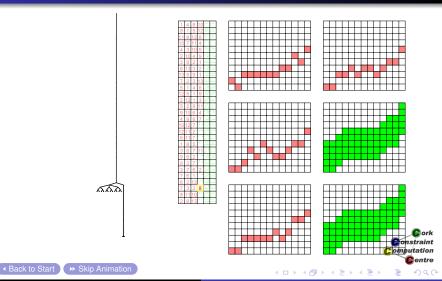


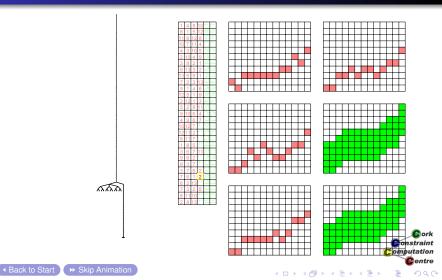


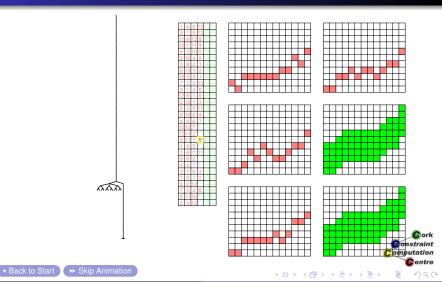


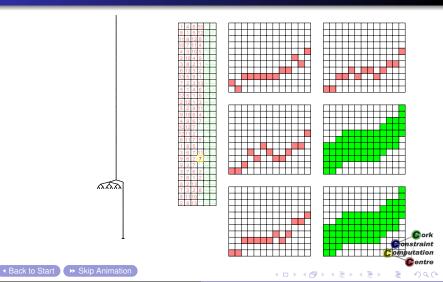


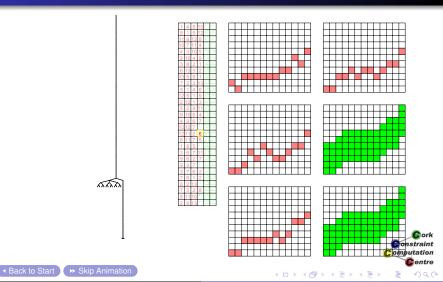


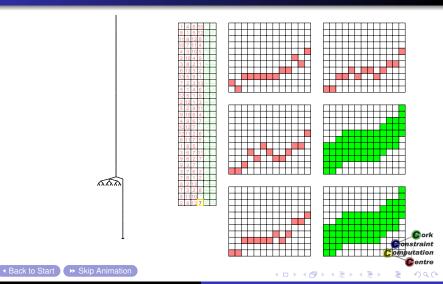


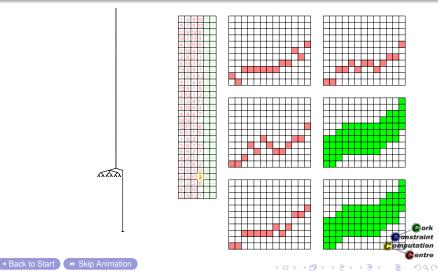


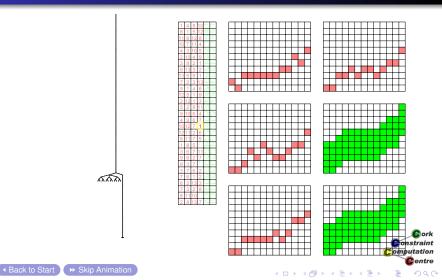


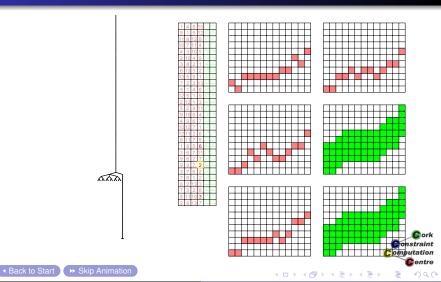


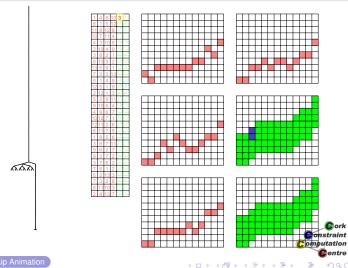


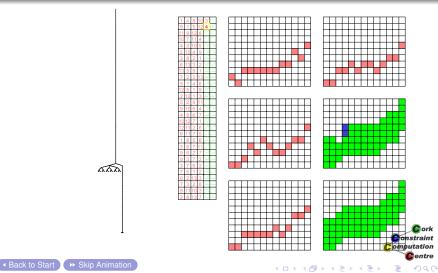


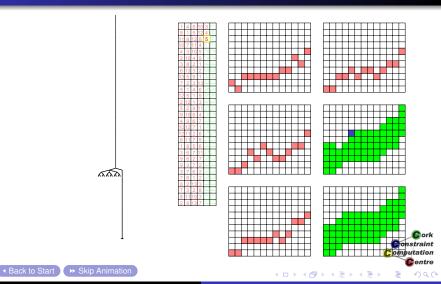


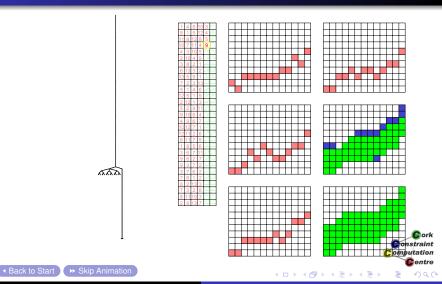


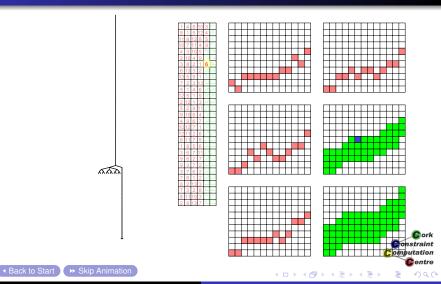


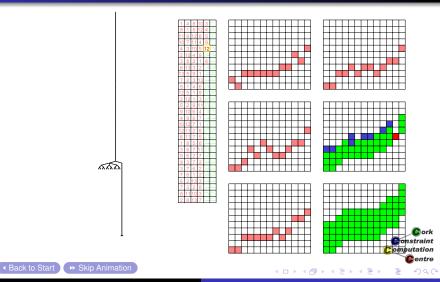


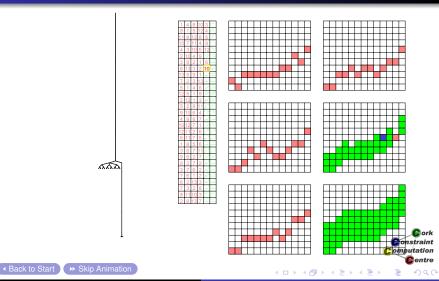


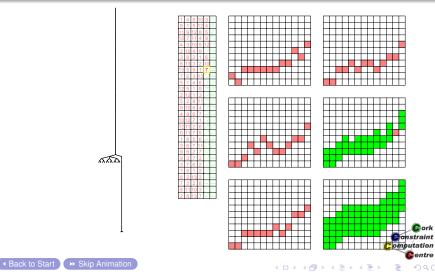


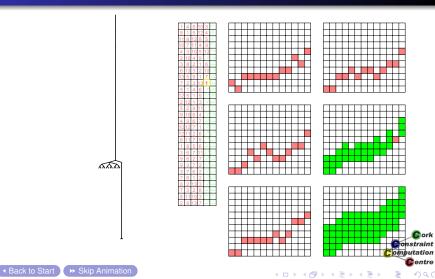


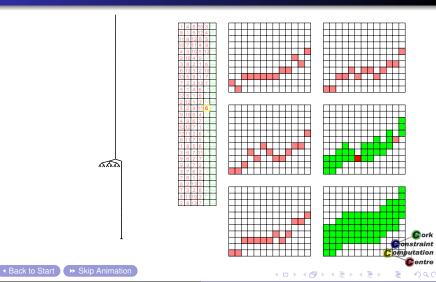


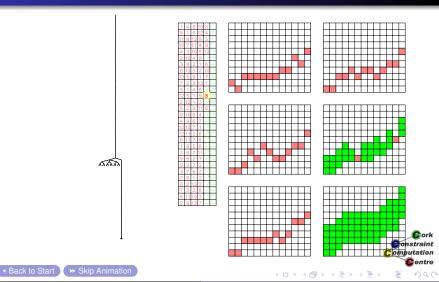


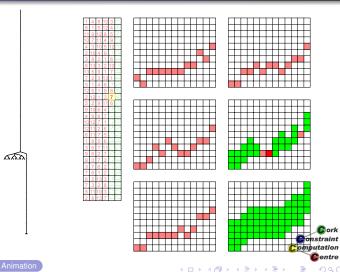


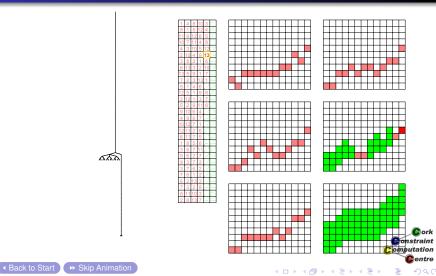


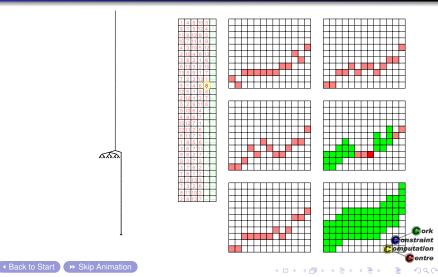


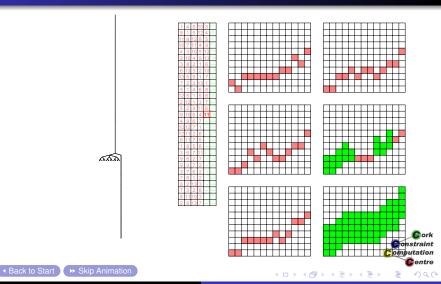


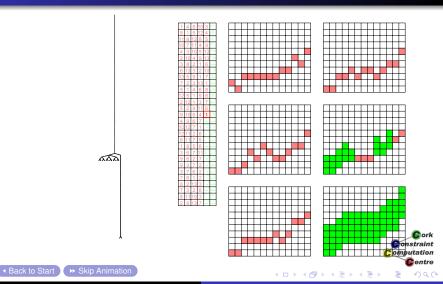


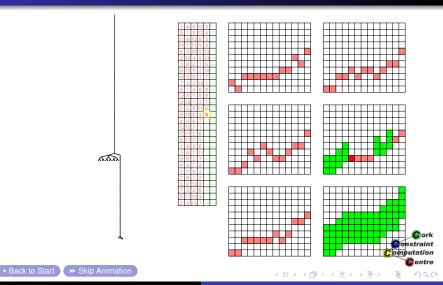


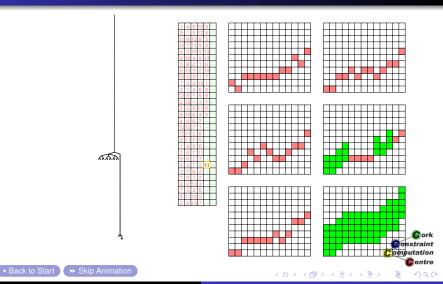


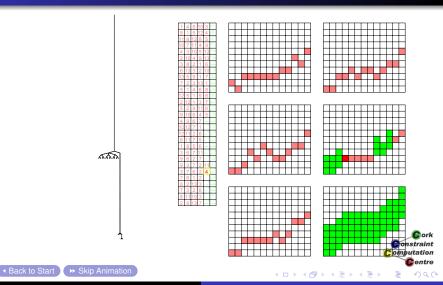


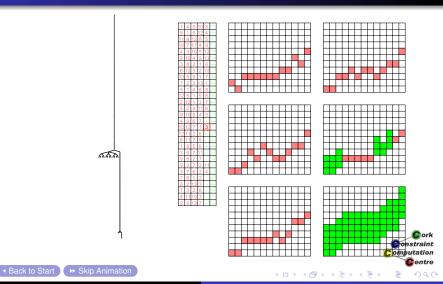


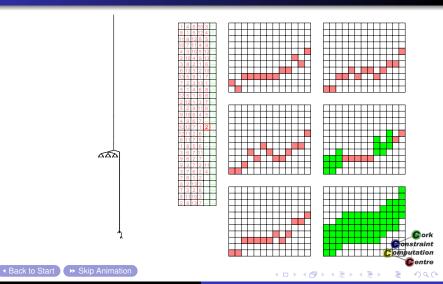


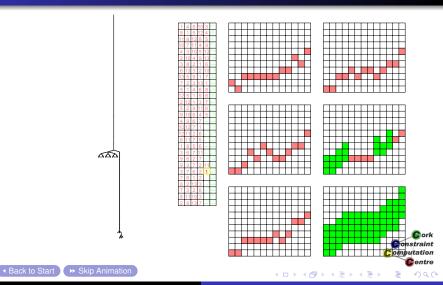


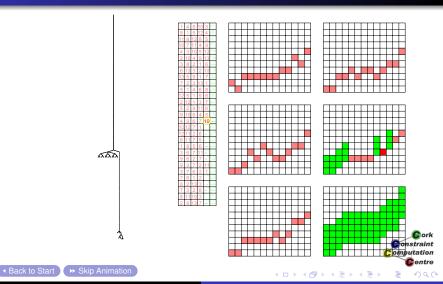


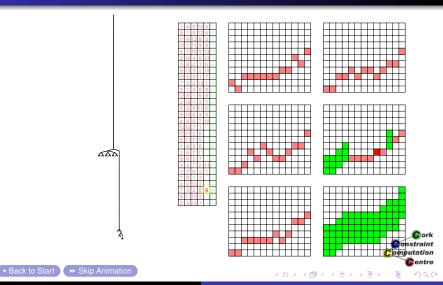


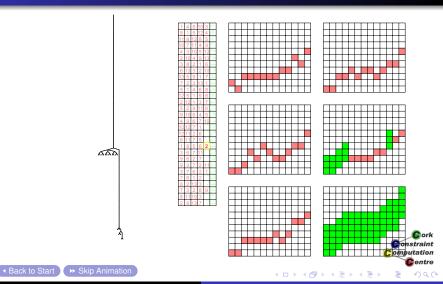


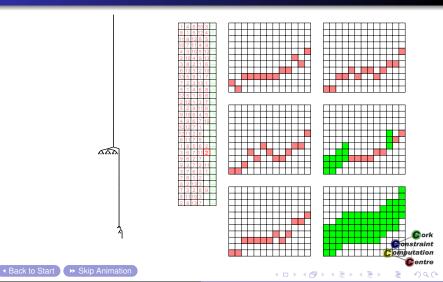


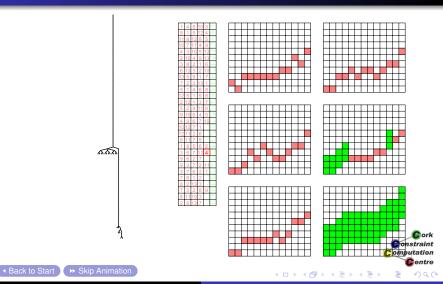


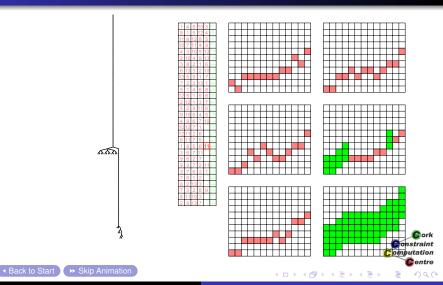


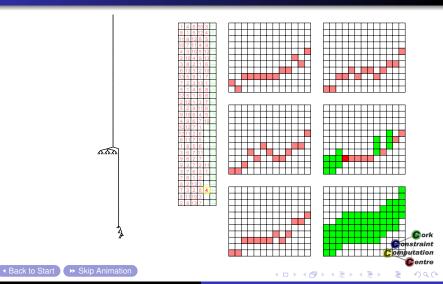


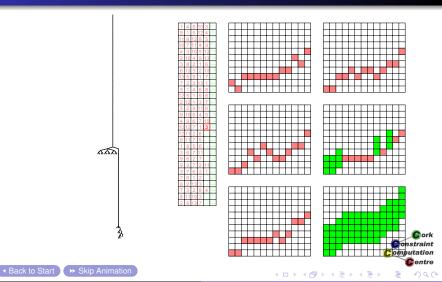


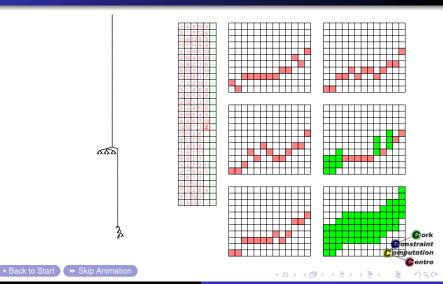


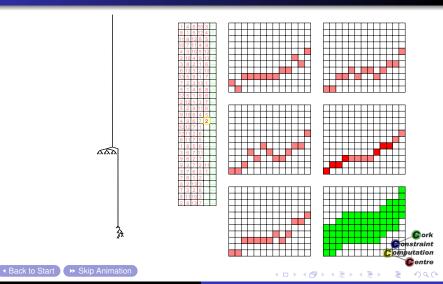


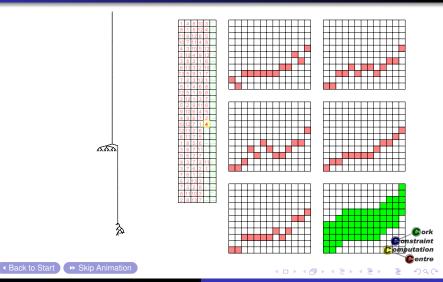


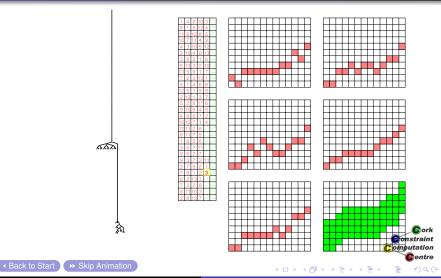


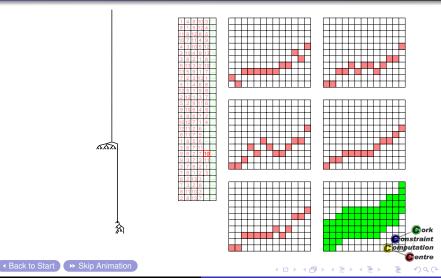




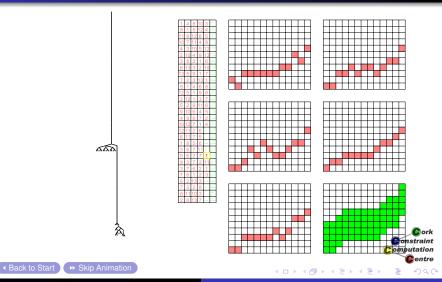




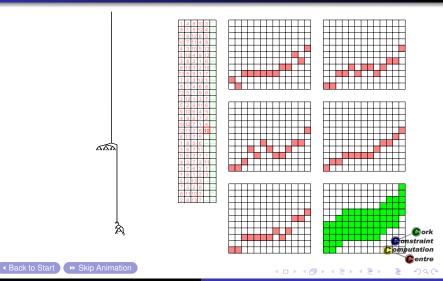


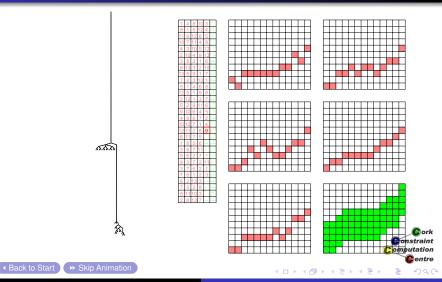


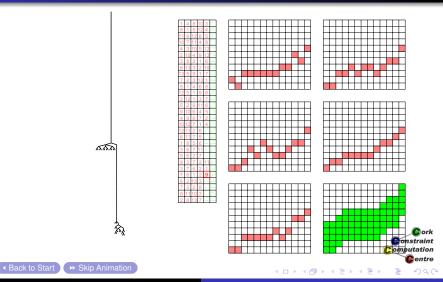
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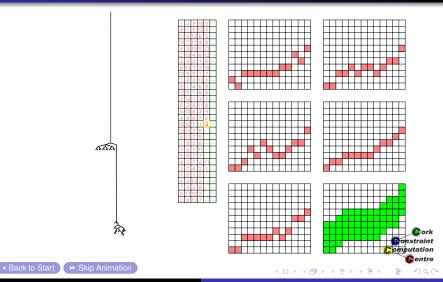


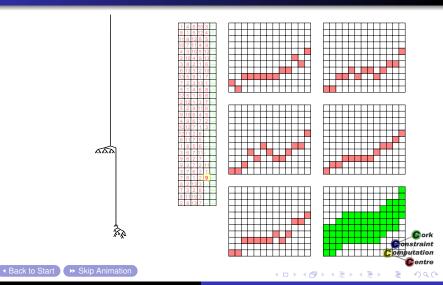
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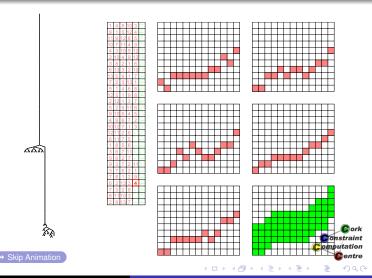


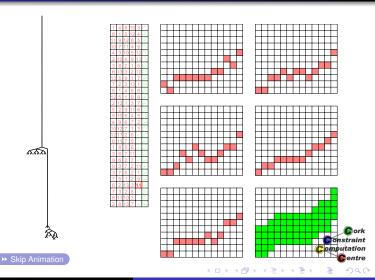






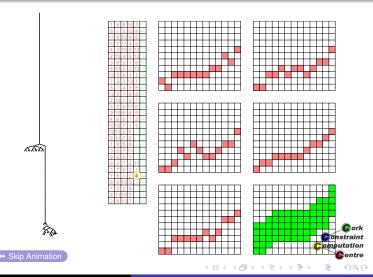






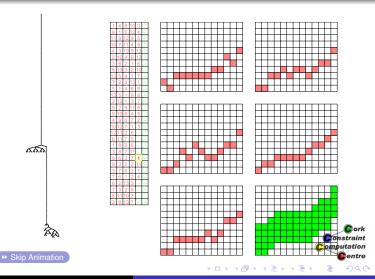
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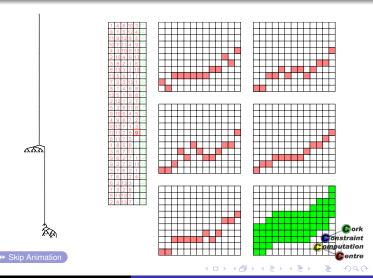
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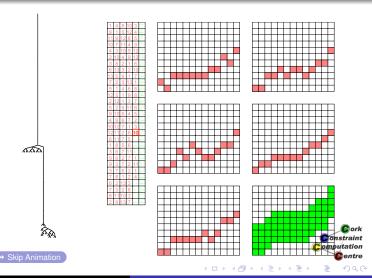


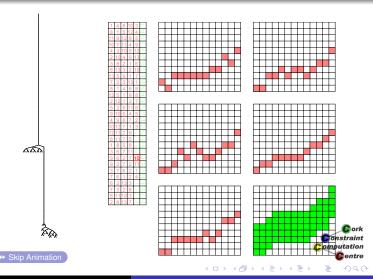
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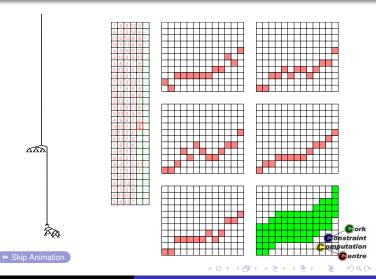
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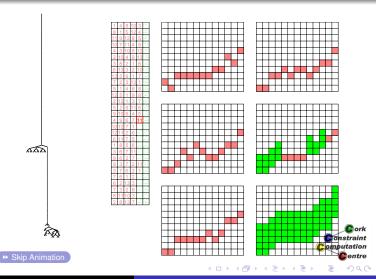


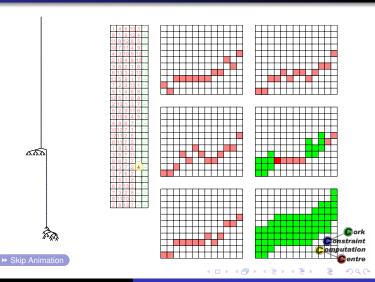




Layered Search
Layered with Credit Search
Randomized with Restart

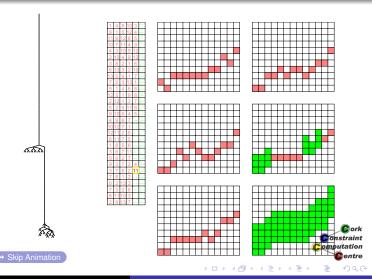
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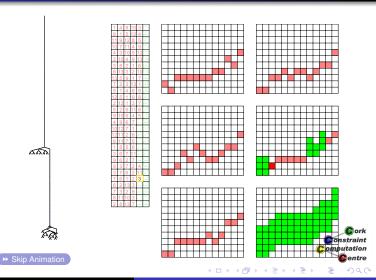


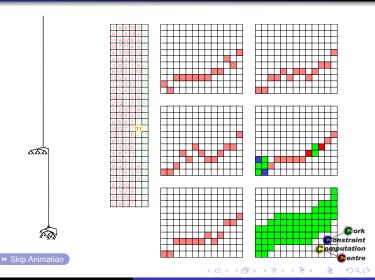


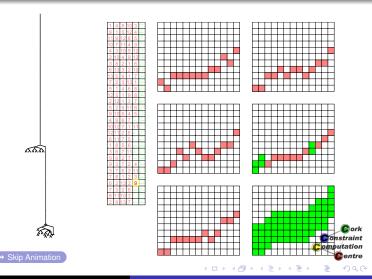
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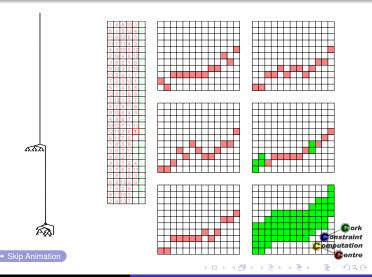
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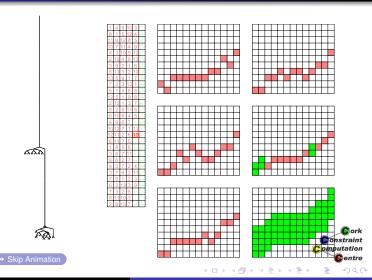


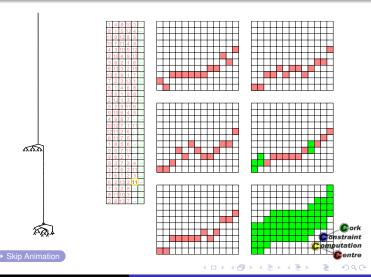


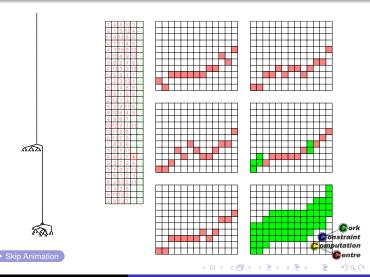


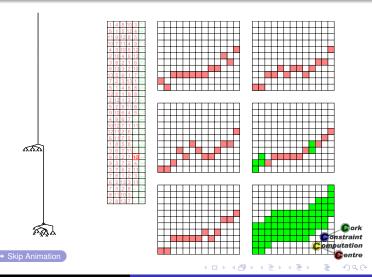


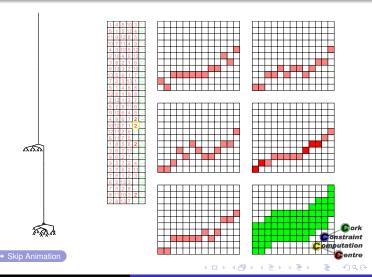


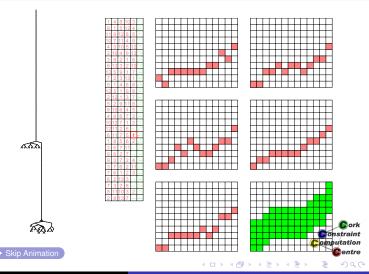


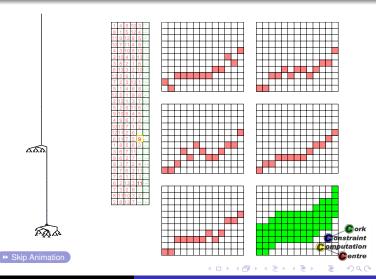




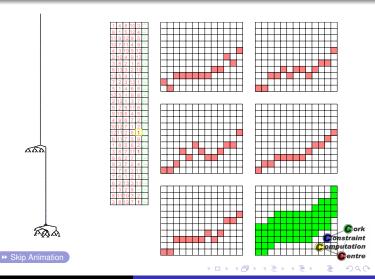


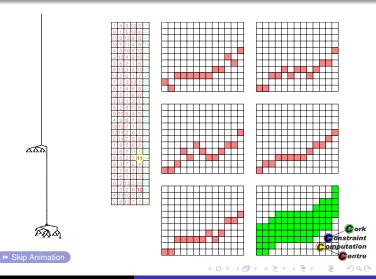


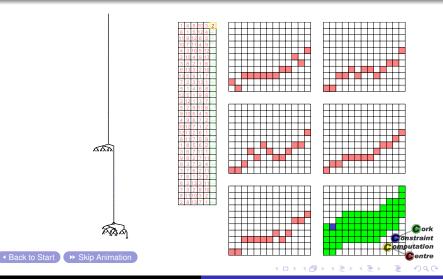




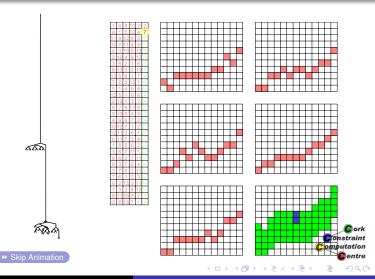
Randomized Search

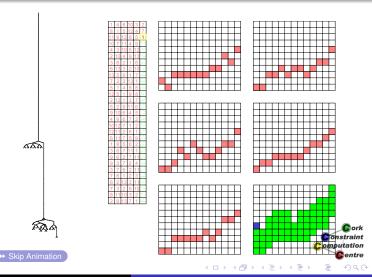


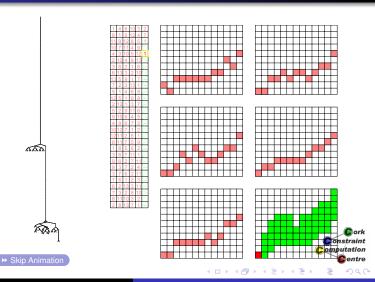


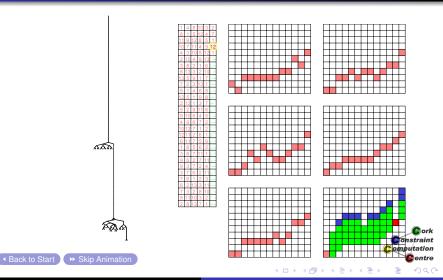


Randomized Search

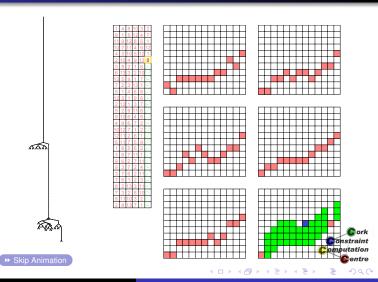


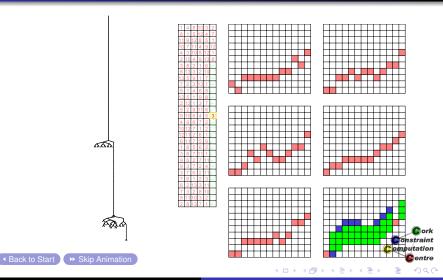




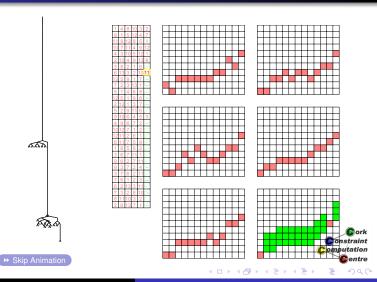


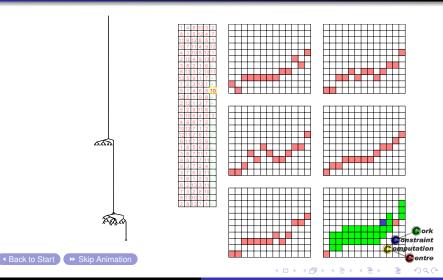
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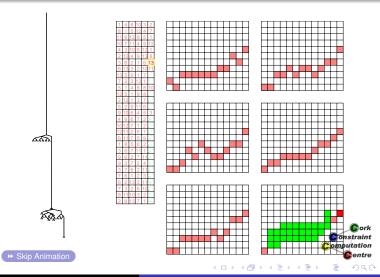


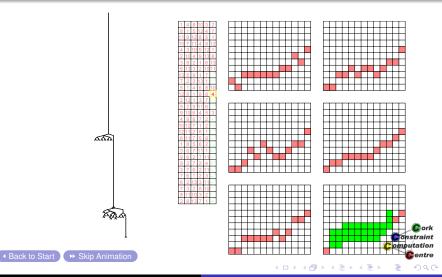


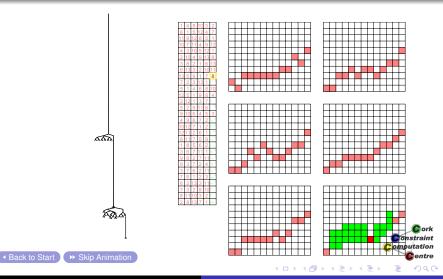
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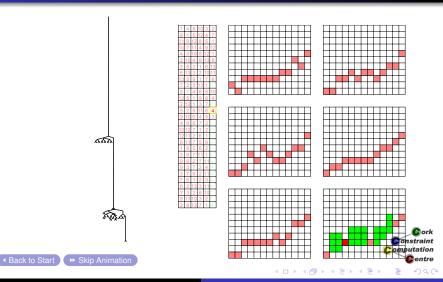




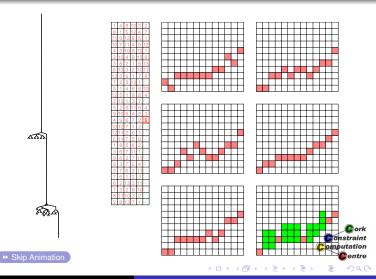


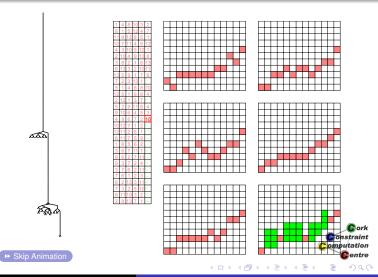




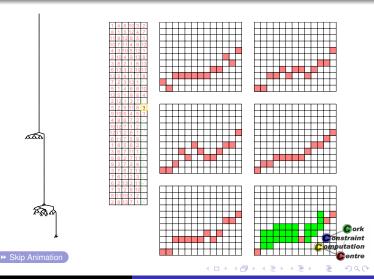


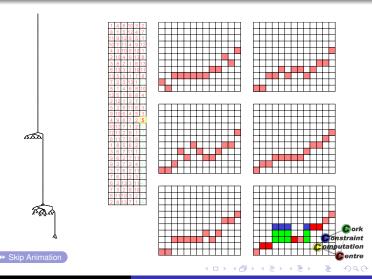
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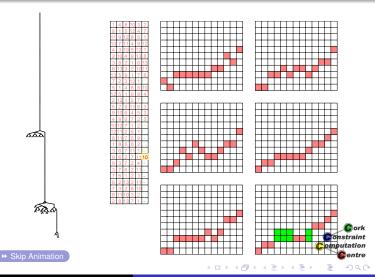


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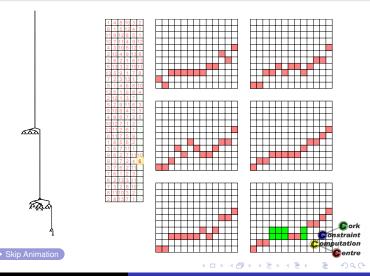


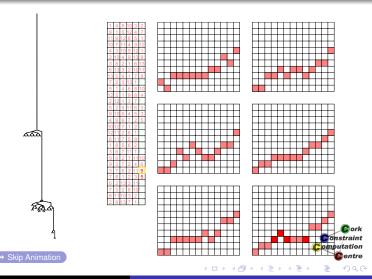


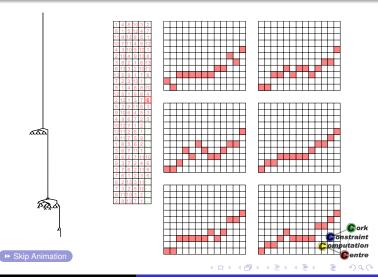
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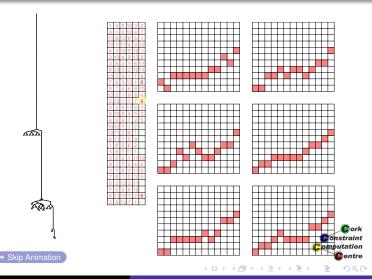


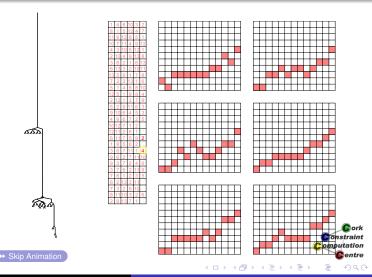
Randomized Search

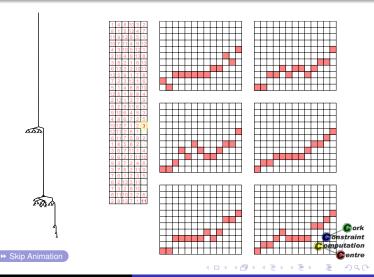


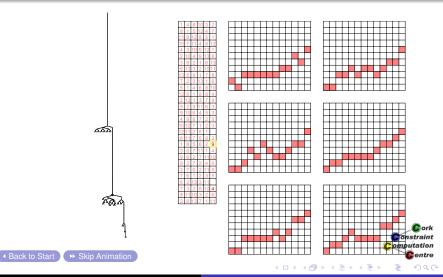


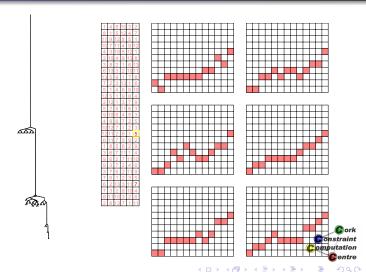












Observations

- Avoids deep backtracking in last time periods
- Perhaps by mixing values more evenly
- Impose fewer disequality constraints for last periods
- Easier to find solution
- Should allow to find solutions with more time periods





Changing time periods

Problem	Size	Naive	FF	Layered	Credit	Random
10	5	0.812	1.453	1.515	0.828	1.922
10	6	14.813	2.047	2.093	1.219	2.469
10	7	79.109	3.688	50.250	3.234	3.672
10	8	-	-	141.609	55.156	6.328
10	9	-	-	-	-	10.281



Observations

- Randomized method is strongest for this problem
- Not always fastest for smaller problem sizes
- Restart required for size 9 problems
- Same model, very different results due to search
- Very similar results for other problem instances





Outline

- Problem
- Program
- 3 Search
- A Further Decomposition



Further Improvement

- Idea: There is no real effect of including later time periods in constraint model
- Only current time period matters
- Decomposition: Set up model for one period at a time



Fine Grained Decomposition

Old	New
Bin packing	Bin packing
Alldifferent	Domain restrictions
Meet at most once	Disequalities between guest boats

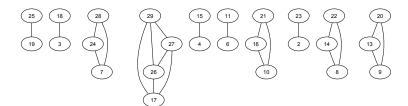


Generated Graph Coloring Problem

- Guest boats = Nodes
- Host boats = Colors
- Disequality constraints = Edges in graph



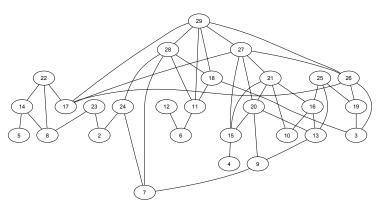
Visualization (Time period 2)







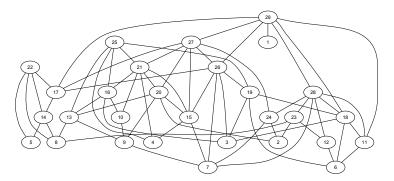
Visualization (Time period 3)







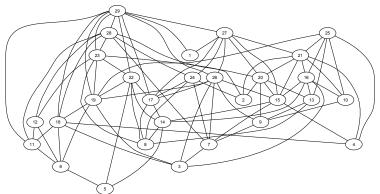
Visualization (Time period 4)







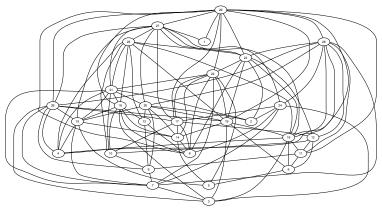
Visualization (Time period 5)







Visualization (Time period 6)





Solving the Graph Coloring Problem

- Use disequality constraints
 - Weak propagation
- Extract alldifferent constraints
 - Edge clique cover problem
 - Choice of consistency method
- Use somedifferent global constraint
 - Heavy
 - Interaction with bin packing constraint





Comparison to Comet

_			F01	:D0 - 0 0					
		ECLiPSe 6.0				Comet			
Nr	Size	Solved	Min	Max	Avg	Solved	Min	Max	Avg
1	6	100	0.187	0.343	0.226	100	0.33	0.38	0.35
1	7	100	0.218	0.515	0.271	100	0.39	0.49	0.44
1	8	100	0.250	2.469	0.382	100	0.50	0.72	0.57
1	9	100	0.266	9.906	1.253	100	0.74	1.46	1.01
1	10	100	0.375	136.828	23.314	100	1.47	41.72	4.68
2	6	100	0.218	2.375	0.624	100	0.37	0.52	0.43
2	7	100	0.266	3.453	1.117	100	0.47	1.64	0.73
2	8	100	0.297	15.421	2.348	100	0.75	7.16	2.69
2	9	100	0.469	107.187	20.719	99	4.41	162.96	33.54
3	6	100	0.219	3.266	0.551	100	0.37	0.56	0.43
3	7	100	0.250	3.734	0.889	100	0.49	1.45	0.74
3	8	100	0.296	21.360	2.005	100	0.84	11.64	2.85
3	9	100	1.078	173.266	34.774	96	4.41	164.44	40.10
4	6	100	0.219	9.922	2.443	100	0.39	0.72	0.47
4	7	100	0.360	25.297	3.531	100	0.55	2.33	0.87
4	8	100	0.438	53.547	8.848	100	1.23	11.38	3.68
4	9	63	3.062	494.109	206.324	94	8.35	166.90	59.55
5	6	100	0.203	7.922	1.498	100	0.53	5.29	1.67
5	7	100	0.266	28.000	5.889	100	1.77	132.82	29.72
6	6	100	0.219	15.219	2.147	100	0.58	31.84	2.74
6	7	100	0.407	64.312	11.328	88	3.24	152.37	56.92





More Information

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