Solving Complex Design Layout Problems

Invited Workshop Speaker

5th UK e-Science All Hands Meeting

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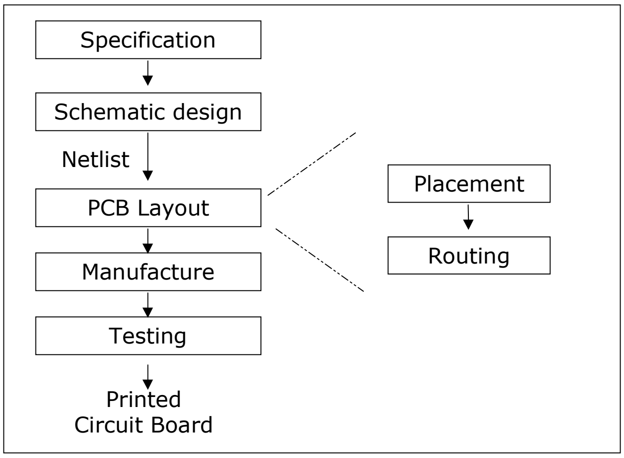
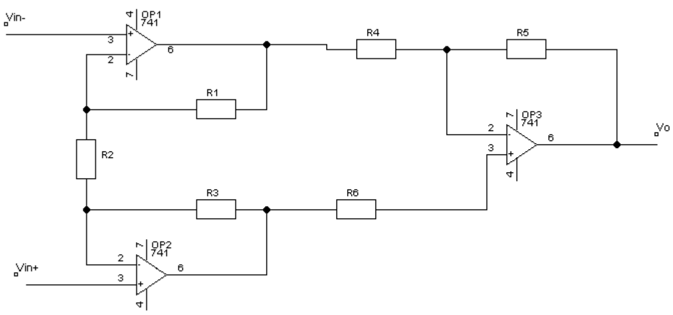
Outline

- PCB design automation research
- Problem complexity (combinatorial explosion)
- Single workstation solution strategies
- Distributed client/server solution strategies
- Conclusions

PCB Design Process



Schematic Design



A schematic diagram of a three op-amp instrumentation amplifier.

Netlist

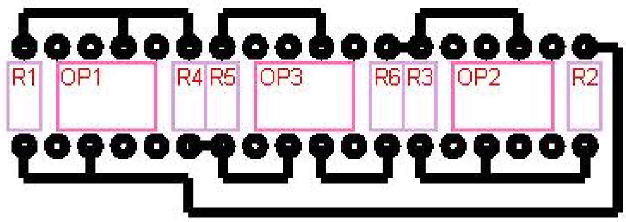
```
COMPONENT 'OP1' = 741
COMPONENT 'OP2' = 741
COMPONENT 'OP3' = 741
COMPONENT 'R1' =
COMPONENT 'R3' =
COMPONENT 'R2' =
COMPONENT 'R4' =
COMPONENT 'R6' =
COMPONENT 'R5' =

; ======+ The net list

NET  'N000000' =  (OP1,4)
NET  'N000001' =  (OP1,3)
NET  'N000002' =  (OP1,7)
NET  'N000003' =  (OP2,4)
NET  'N000004' =  (OP2,3)
NET  'N000005' =  (OP2,7)
NET  'N000006' =  (OP3,4)
NET  'N000007' =  (OP3,7)
NET  'N000008' =  (OP3,6),(R5,1)
NET  'N000009' =  (R1,1),(R2,1),(OP1,2)
NET  'N000010' =  (R1,2),(OP1,6),(R4,2)
NET  'N000011' =  (R3,1),(R2,2),(OP2,2)
NET  'N000012' =  (R3,2),(OP2,6),(R6,2)
NET  'N000013' =  (R4,1),(R5,2),(OP3,2)
NET  'N000014' =  (R6,1),(OP3,3)
```

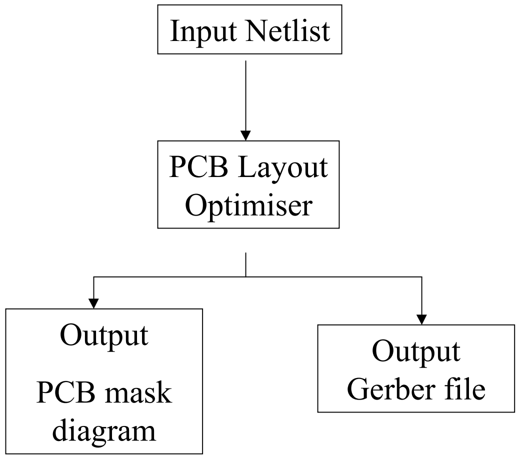
A netlist is a list of node connections which correspond to the schematic. It also contains a list of components. Generating a netlist is called schematic capture.

PCB Layout

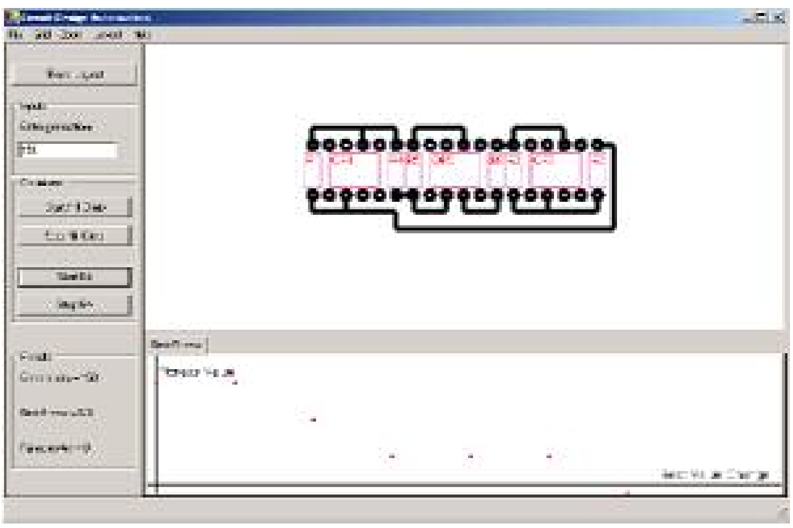


The aim is to automatically generate an optimised scale drawing of the PCB layout for traditional copper-etch PCB board manufacture. DIL packages have pins spaced on a 0.1 inch (2.54mm) grid. Track widths and track clearances typically 0.025 inch (0.635mm).

PCB Layout Optimiser



Screenshot of PCB Layout Optimiser



Coding Strategy

- Component placement and routing is based on using grid positions
- By swapping the positions of parts on the PCB grid (iterative placement) and the order in which pins are routed an optimal layout can be sought
- The problem is coded as a combinatorial or order-based problem (component position order and route order arrays are defined)

Track Routing

•The Lee maze routing technique is used for track routing
•The algorithm works in two phases:-

1. Wave propagation
2. Re-tracing

Wave propagation -label nodes with distance measure radiating from source

S 0	1	2	3
1	2	3	
	3	4	5
5	4	5	T 6

Orthogonal Routing

Label nodes with Manhattan distance

S 0	1	2	3
1	1	2	
	2	2	3
3	3	3	T 3

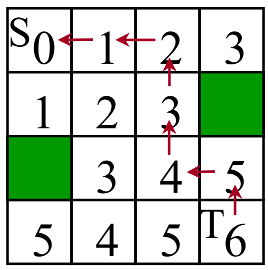
Diagonal Routing

Diagonal labelling scheme

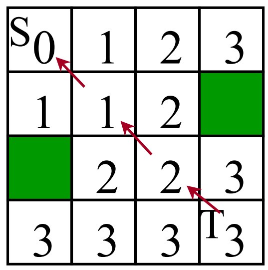
Track Routing

Re-tracing - choose path that always decreases distance to source

The Lee method finds a shortest path connecting *S* and *T*.



Orthogonal Routing



Diagonal Routing

Combinatorial Explosion

- The placement problem
- If the number of components to place is N then the number of possible combinations to search is N! (Factorial)
- In the instrumentation amplifier circuit shown N= 9
- N!=(362 880) solutions

Combinatorial Explosion

- The automated layout of the instrumentation amplifier circuit is a small problem
- With 10 components there are N! =3,628,800 possible solutions to check
- With 16 components there are $N!=2.092x10^{13}$ solutions to check
- Thus the order of the placement problem using an exhaustive search is O(n!)

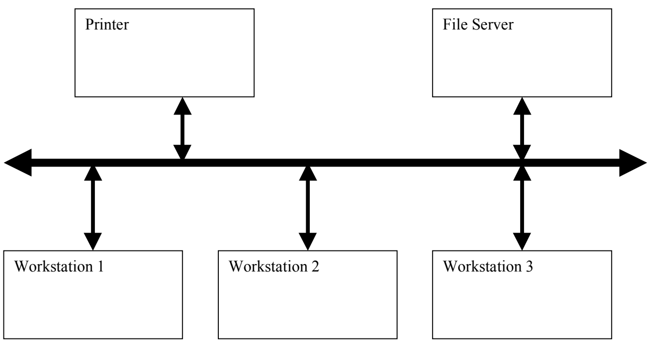
Combinatorial Explosion

- The number of possible placements for 10 components is 3,628,800. Assuming that a computer takes one second to evaluate the quality of the solution of a single placement an exhaustive search will take 1008 hours to find the best solution
- Trying to get an exact solution by evaluating every possible placement solution to determine the best is impractical with circuits with high component number

Solution Strategies

- With circuits with a reasonable number of components a heuristic algorithm (e.g. genetic algorithm) can be used to efficiently search candidate placement/routing solutions (Crispin 2006)
- As the problem becomes more complex a new solution strategy is needed
  - On a single workstation our work is investigating intelligent placement algorithms based on component connectivity thereby reducing the placement search
  - Another option is to consider distributed client server solution strategies

Distributed Client/Server Solution Strategies



Distributed Client/Server Solution Strategies

- An alternative solution strategy would be to distribute the problem using a network of workstations
- Code the problem as a set of agents
- Agent for component placement
- Agent for routing
- Agent for design rule checking etc...

Agents

- An agent can be considered as an autonomous software system that is capable of reasoning
- Each agent makes their own decisions and communicate their actions to the other agents in the system through negotiation
- TCP/IP communication can be used
- Agents using the client/server model can be implemented using a network of workstations

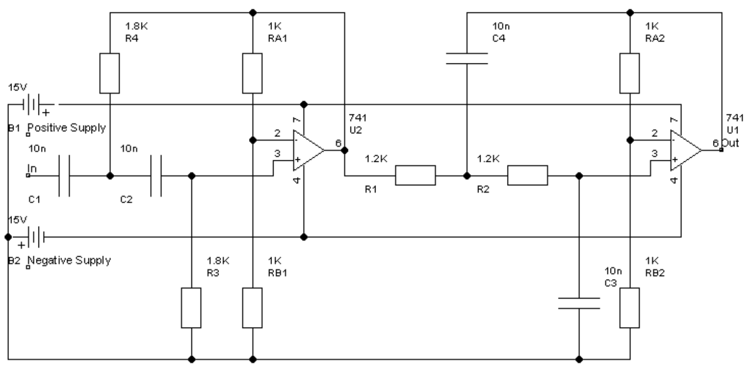
Work on CAD Agents

Previous research (Crispin et. al.2005) has developed an agent based CAD layout simulator for training leather cutters known as clickers

Circuit Partitioning

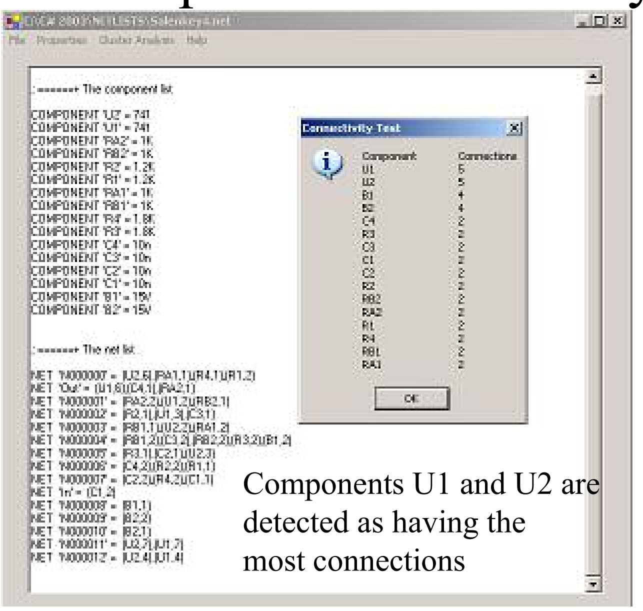
- An alternative approach to the use of agents would be to partition the circuit and distribute smaller layout problems to a set of workstations
- Current work on connectivity based placement will be useful with this approach and the layout problem could be partitioned and distributed based on connectivity clusters

Circuit Partitioning



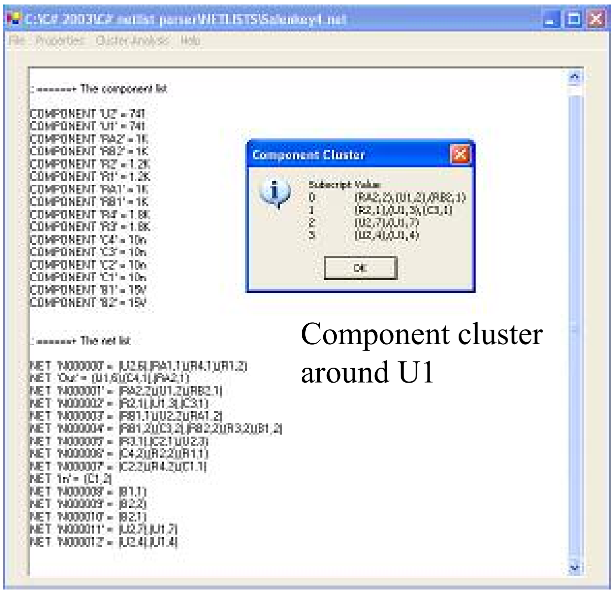
Salenkey band pass filter (two circuit clusters around u1 and u2)

Component Connectivity



Components U1 and U2 are detected as having the most connections

Connectivity Cluster



Conclusions

- The automatic generation of PCB layouts can be coded as a combinatorial optimisation problem
- As design complexity increases new solution strategies are needed if optimal layouts are to be auto-generated in an acceptable time
- Distributed client/server solution strategies could have an important role in future advances in PCB design automation

Selected References

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