Coding the Objects in Place and Route CAD

Yoji Kajitani

Senior Professor
Japan Advanced Institute of Science and Technology
kaji-you@jaist.ac.jp

I am so much thankful to this honor for me. I doubt if I deserve this after great Profs E. S. Kuh and C. L. Liu;

I have no word to express my surprise. I must be rather expected to do a formal saluting before ISPD people in English what had my research been so far.

But it is not interesting and not what I could do well.

Instead

I have come to an idea that
this is a given opportunity to speak out
my recent small discovery.

It is about Place and Route, surely a common interest to all the ISPD attendees.

This topic covers the early stage of CAD researches
which a senior old researcher like me could give.

In 1970's when the age was changing from "analog" to "digital",
our generation of theory oriented researchers
in Electrical Engineering

had been more or less forced to shift their positions
to discrete algorithms and applications.

Automation of "Place and Route"
was the subject that attracted us most.

Have I retired?
People would say
it should be
for a better rest of the life:
However,

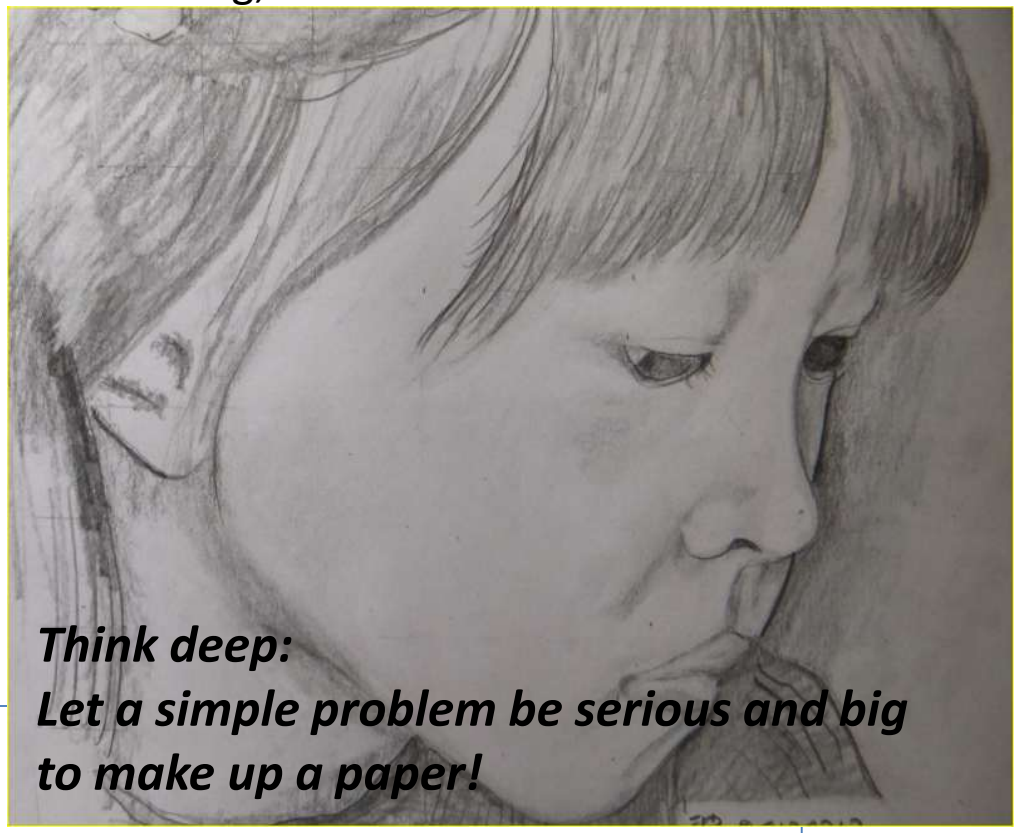
Yet I claim, I do not stop to yell!

But What particular?

These days, the computer was frail and feeble and
CAD was a branch of computer science;

every subject was a target of mathematical thinking;
(at least in Japan)

However, most of the research themes were initiated in USA, Silicon Valley, what we could do is:



Think from the beginning:

"Physical design" is what?
It is to transform the data of "logical existence" to that of "physical existence".

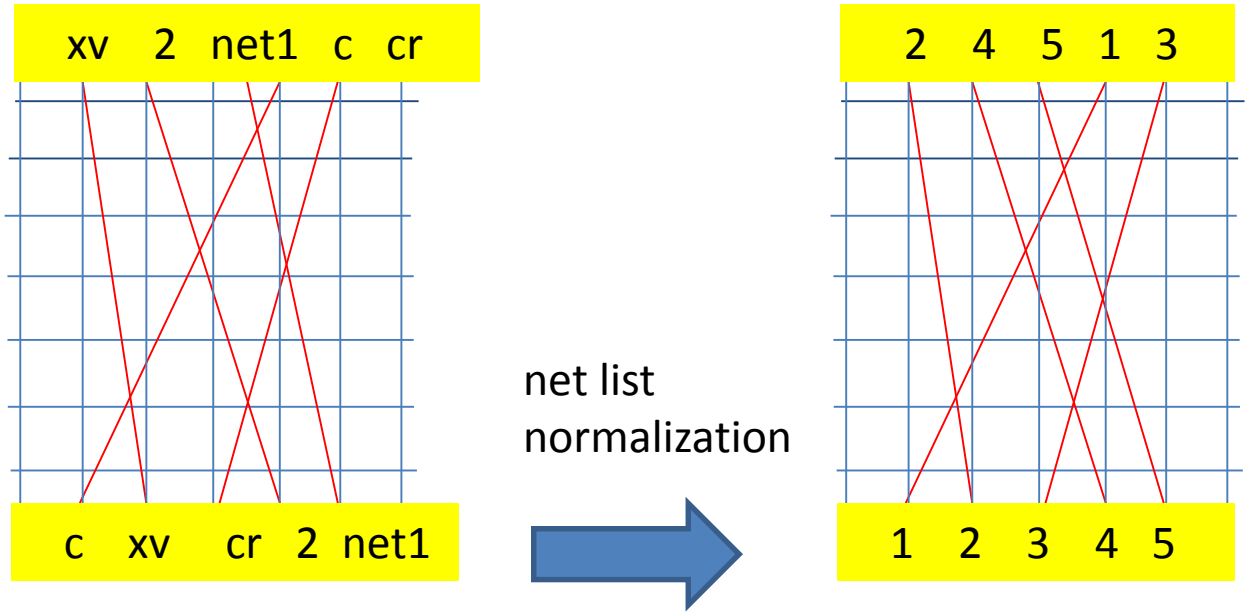
What is meant by "data"?

The subject I met first was channel routing

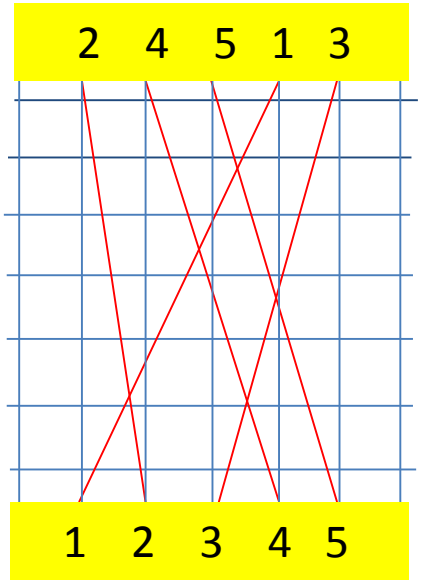
Complete a disjoint set of paths
that connect nodes of the "same label".

Net List : {xv, 2, net1, cr}

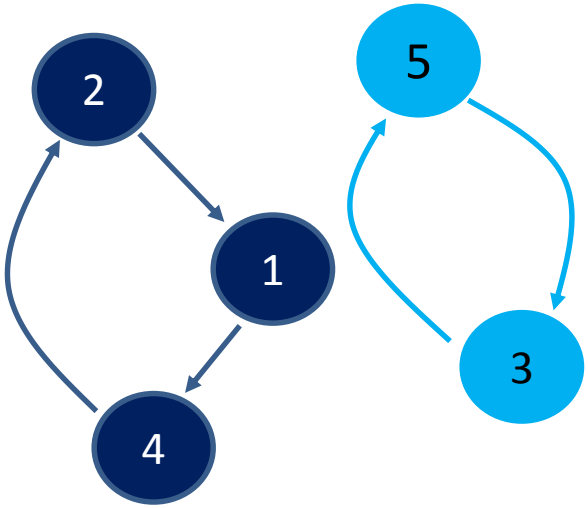
The problem is uniquely defined
in terms of a permutation P=(2 4 5 1 3).



Method(s)

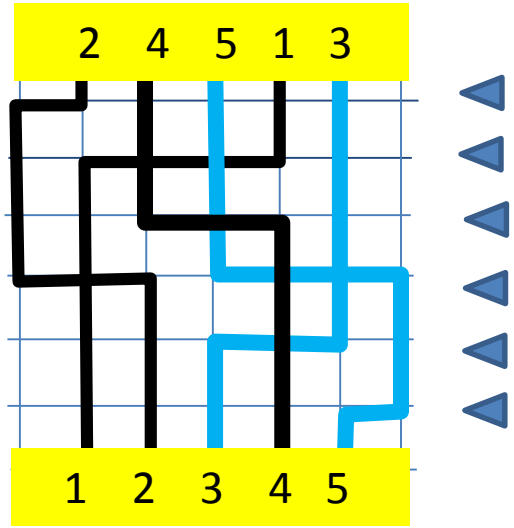


vertical constraint graph

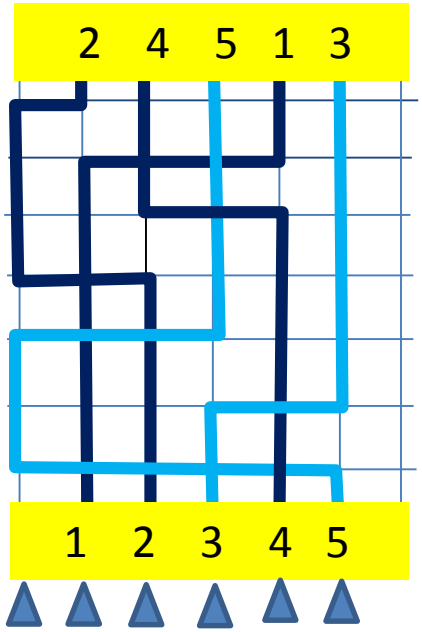


At least
(n+1)x(n+1)

Optimal in rows 7x6

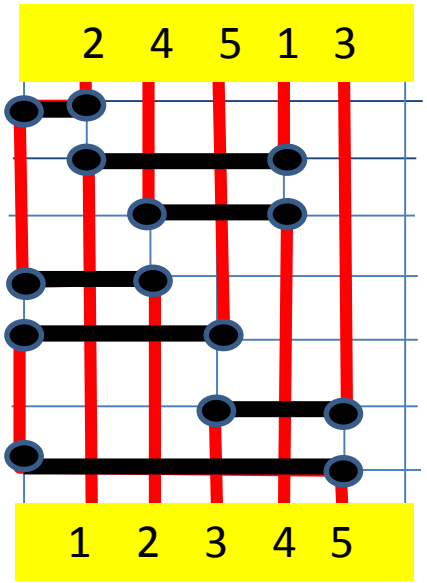


Optimal in columns 6x7

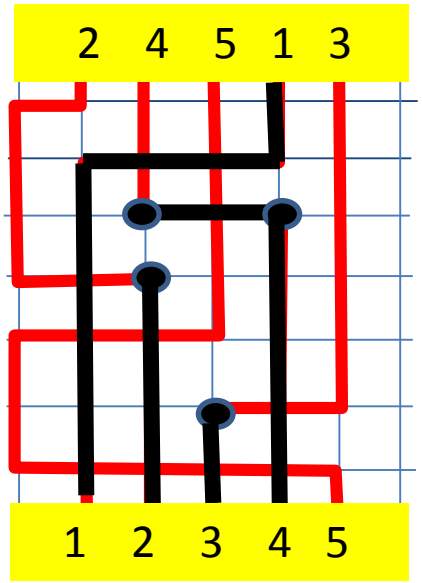


Layer assignment of segments?

HV rule : 14 vias

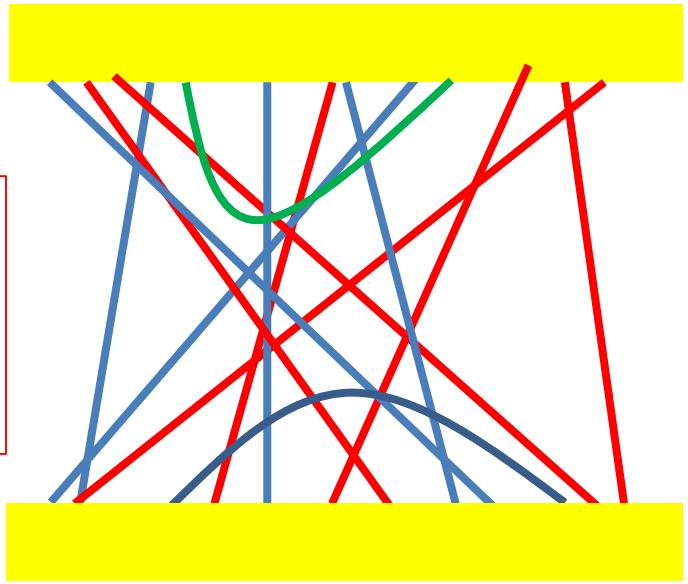


Free: 4 vias



??????

What else known?



Optimization is NP-hard;

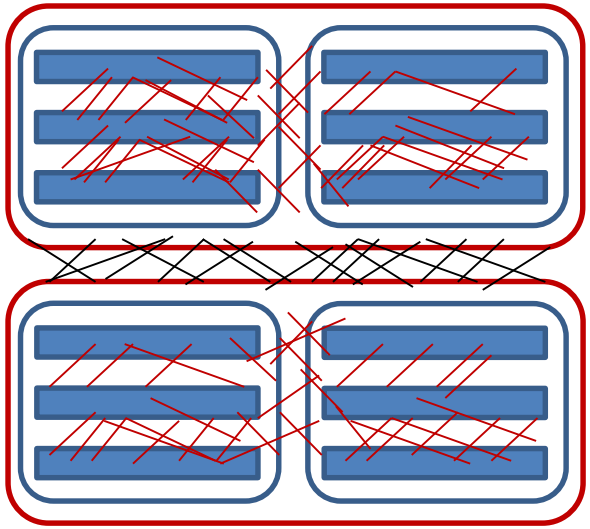
Yes or No? of a success for a given area?
is NP-C.

No one knows the exact solution
so that it has been a good theme for contest
to compete the success ratio.

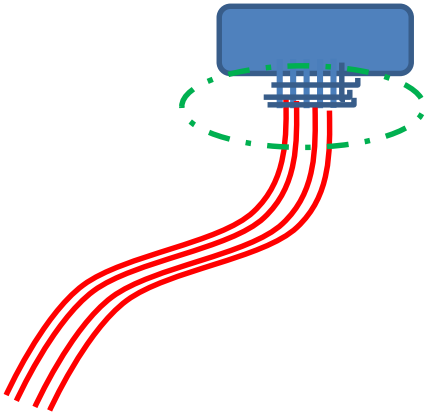
Even
the term "difficult problem" was an admitted common word.
(Deutch's difficult problem, Yoshimura and Kuh)

It looks a small problem to search the corner of the nest.

However,
we could not despise or belittle this problem:
Channel routing is a critical stage in hierarchical IC design.
Also in bus-like routing in PCB and in package design.
Where order arrangement of nets shall be done in the terminal area.



Prediction error accumulates



The end tip of bus-routing is critical.

A weird situation,
no systematic (satisfactory) way
to guarantee the minimally sufficient area .

I hate it.

Not a rescue but:

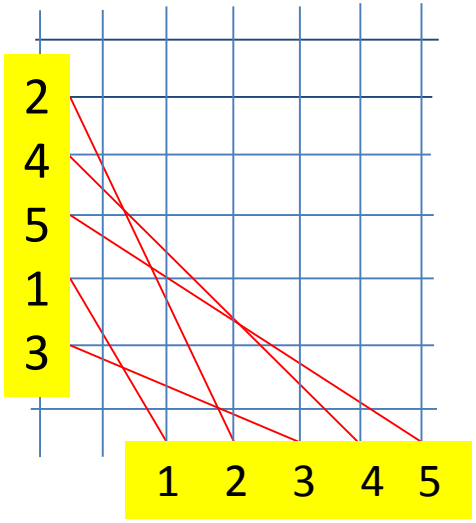
A method was known that achieves
routing
with the minimum number of columns, or
with the minimum number of rows,
but not
with the minimum area.

T. Kawamoto and Y. Kajitani
The minimum width routing of a 2-row 2-layer polycell-layout,
16th DAC, 1979.

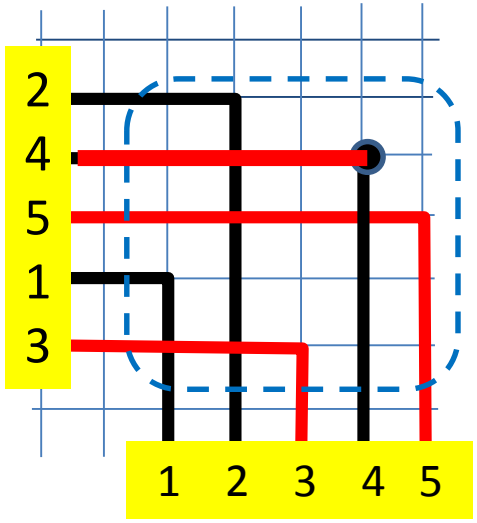
2013-1979=34 years ago

Let us think of a slightly different channel routing.

Side-type channel

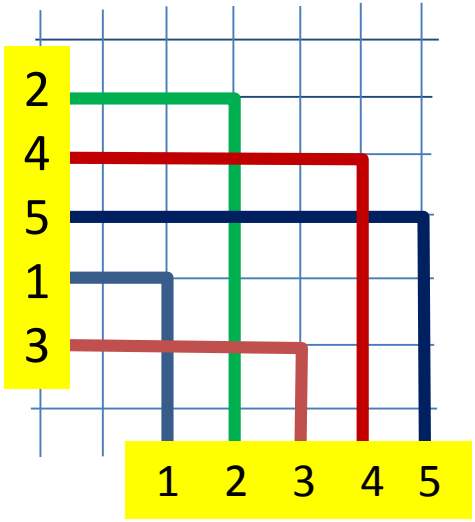


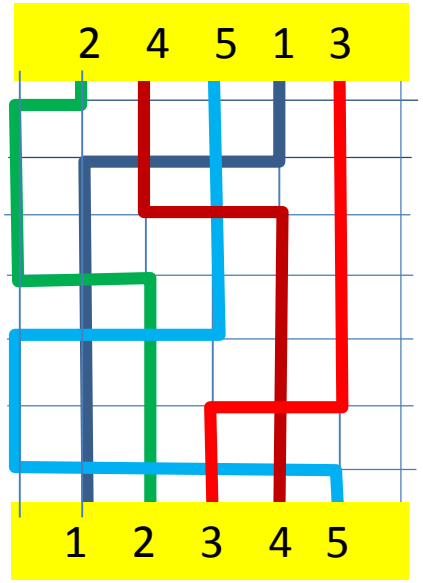
Solution, always optimal in any sense:
nxn area (with 1 via in this case)

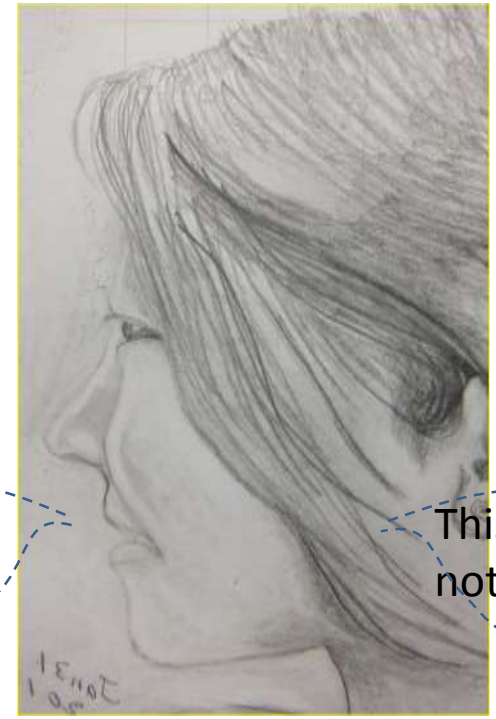


difficult and uses a large area unknown

Easy to achieve an optimum for any netlist

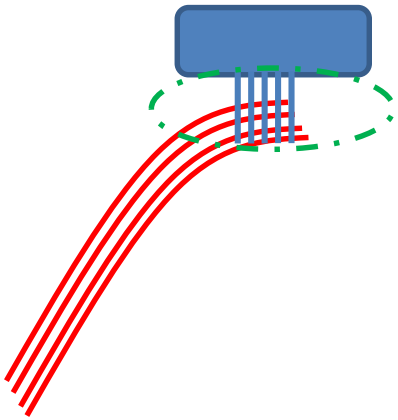


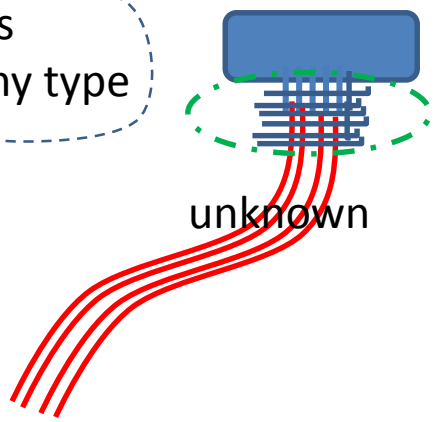




I love this!!

This is not my type





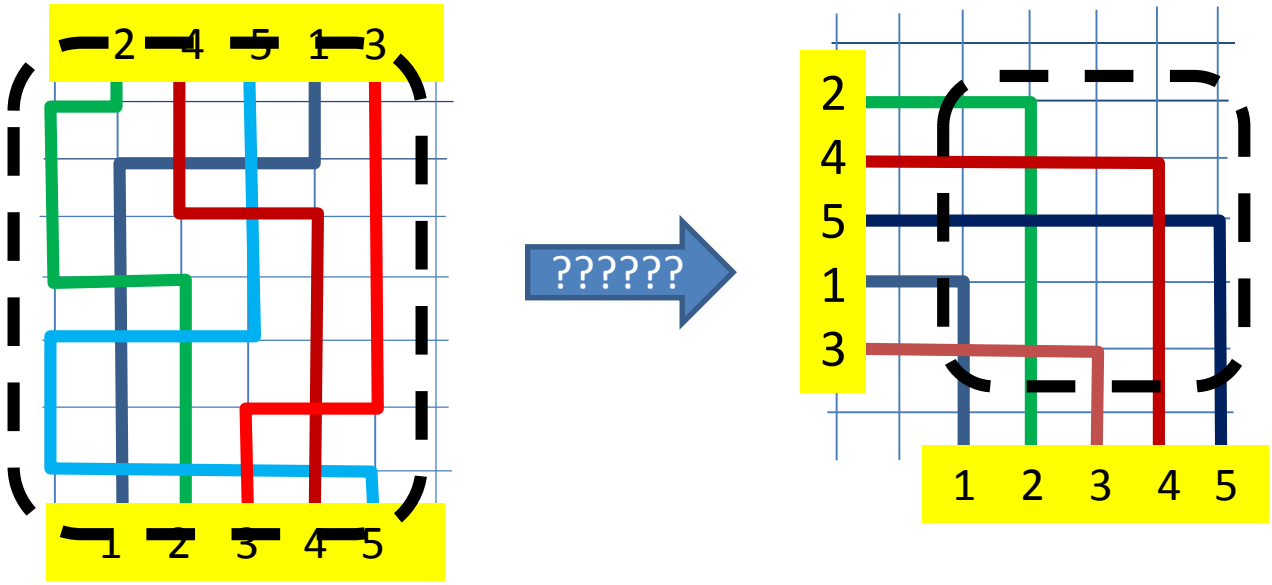
No wonder,
different problems
have different solutions!

My question:

so big different?
as to need different theories?

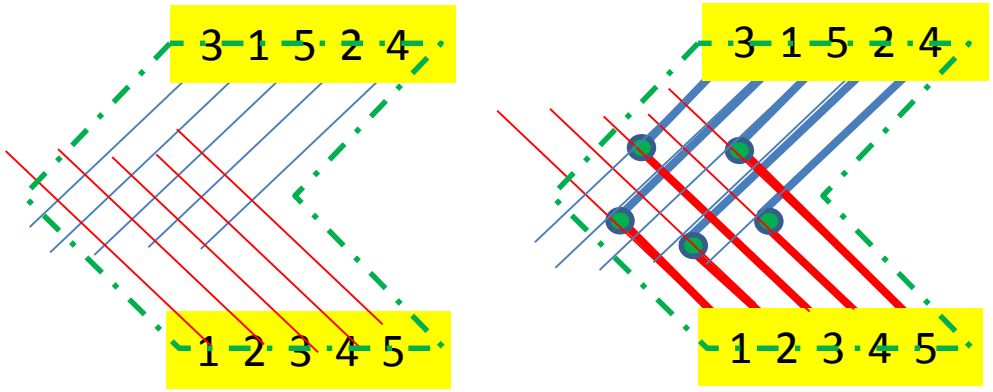
Is there any single theory
that connects two facts.

Have you tried a common technique?
to approach a hard problem
through a combination of solutions
of easier problems.



I got it!

Slant the world!!
instead of route modification



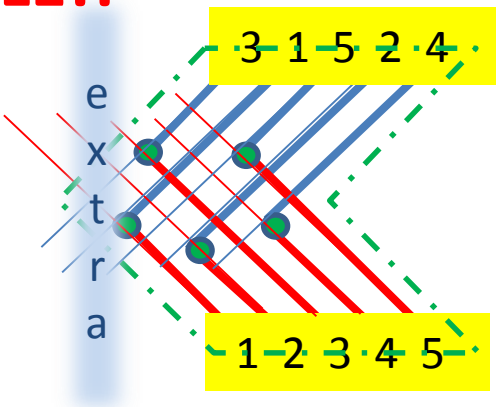
We can get this
as easy as the side-type channel.

Still something I do not like!

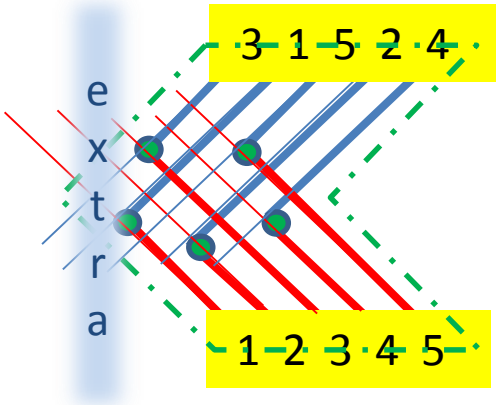
It still needs a certain (unknown) extra area outside:

It uses slant edges:

It is BREAKING THE RULE!!



I love a gentleman
who keeps the rule.



An Example in History:
Christopher Columbus

was successful to stand an egg.

But it was done by breaking the egg:
He violated the game rule.

He was a bad boy!

He was falling to the hell in 1492. People used to say "I told you".

When I was staying at Berkeley in 1980,
I saw a pen-drawing in a gallery at the Fisherman's Warf, SF.

In which,
Christopher Columbus (in Flag ship "St. Maria) is falling at the edge of the world since as people believed the world is flat and ends by the fall.

The title is "**I told you**".

That time, I was taking three babies and
I understood an English usage "I told you"
to bad boys and girls.

Years after, I came to think it is what I need. I was feeling:
The life is strongly regulated by the detailed rules for (almost) nothing.
They say always to me "I told you". I found I was a bad boy.

I looked for and asked friends for the drawing in vein.
I understood it is what I have to draw myself.

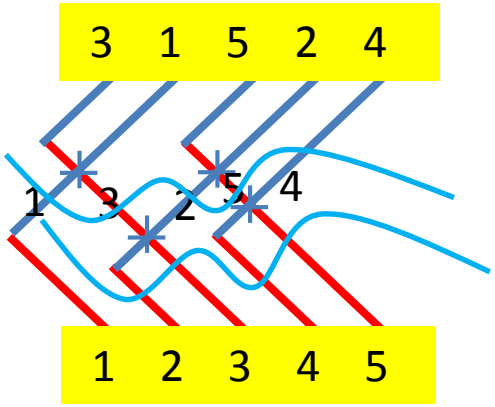
I studies the ship. His ship "St. Maria" was a very small wood ship.
Its copy you can see at Kobe port. Other two associate ships are junk boats.

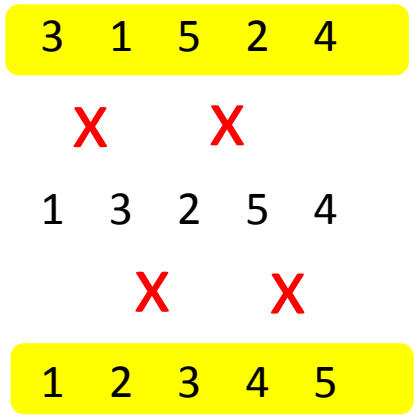
How could they manage this accusation?

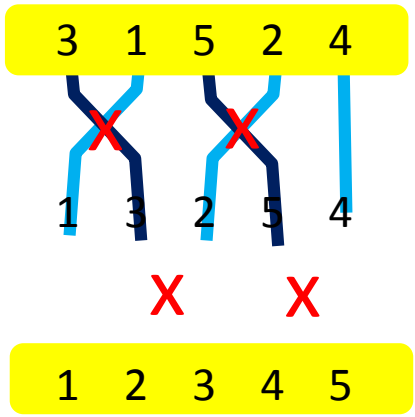
The essence is the cross:

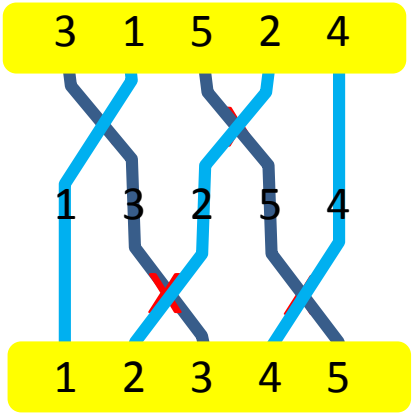
The top crosses lead a sequence partially sorted.

A cross is an exchange:

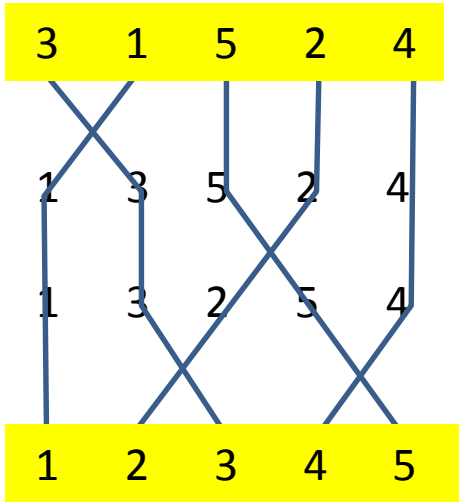


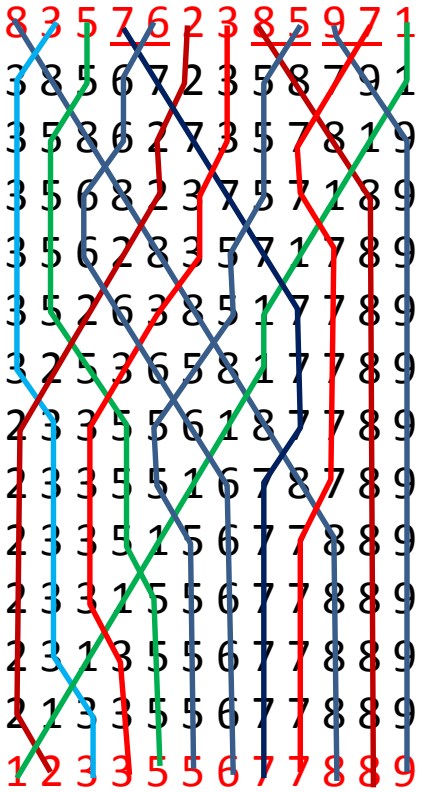


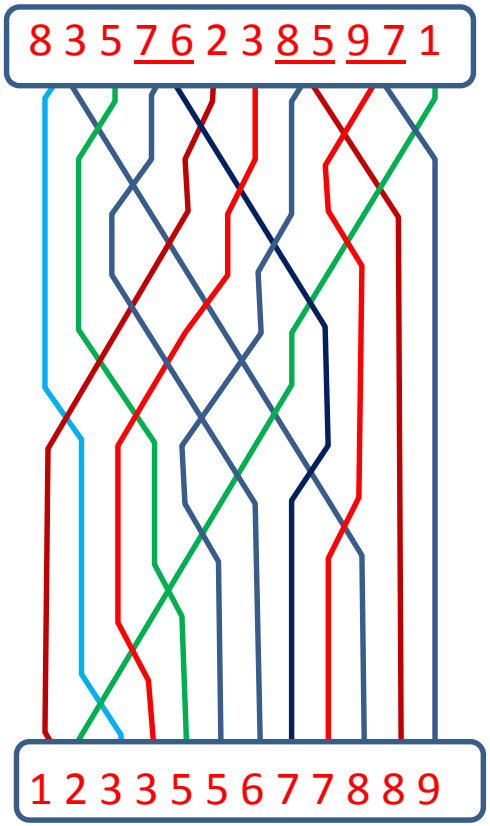




Cross resolution router (Mathematical router)

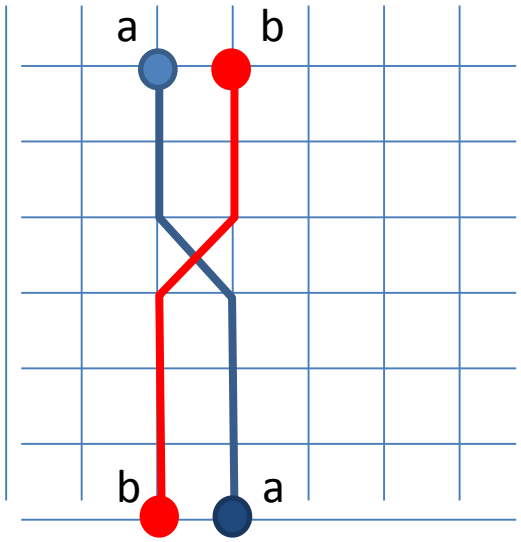


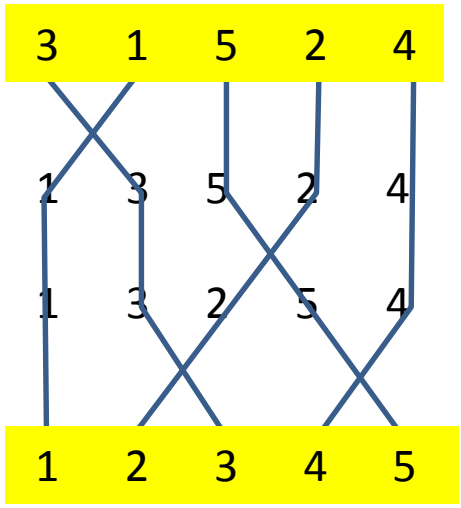


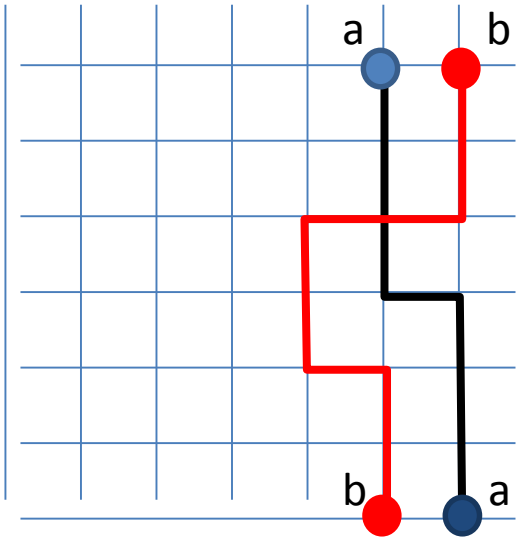


Many good features

Any question?
Why slant-routing not popular so far?

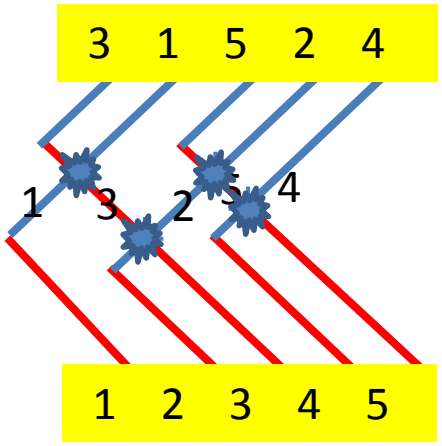




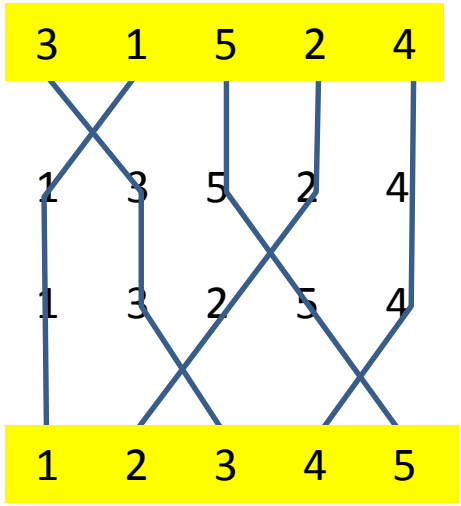


It is a fact;
Not so much interesting!!

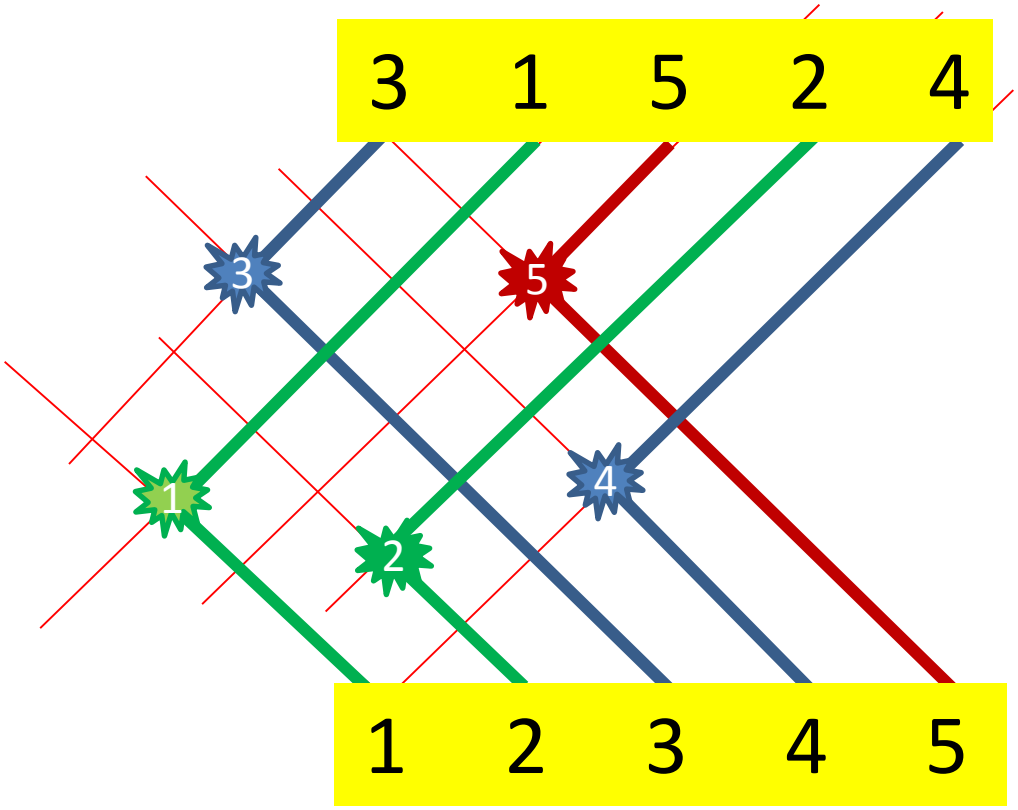
Go to the next topic

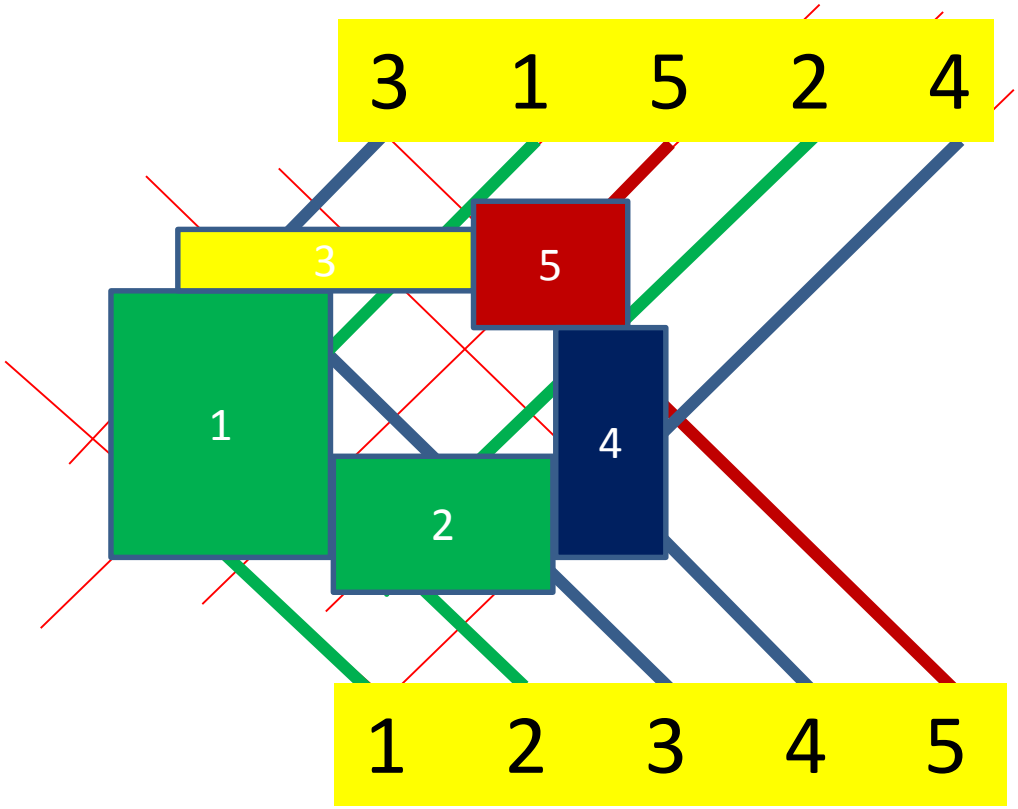


So far, we have noticed the crosses for routing.



If we notice the bends?



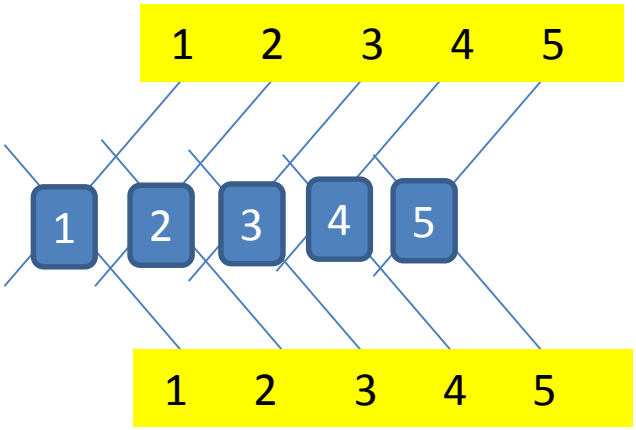


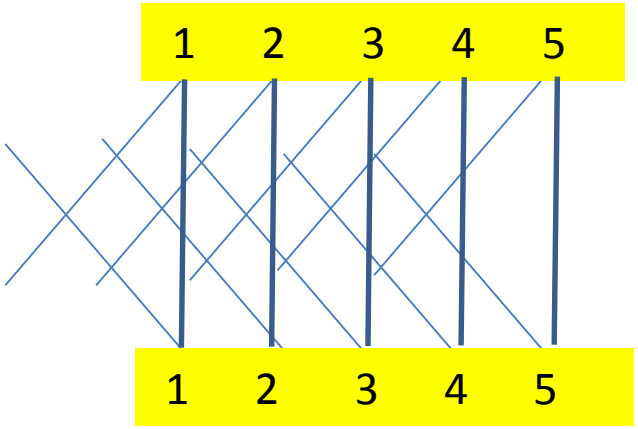
"3" is above "1",
"3" is left of "5", etc.

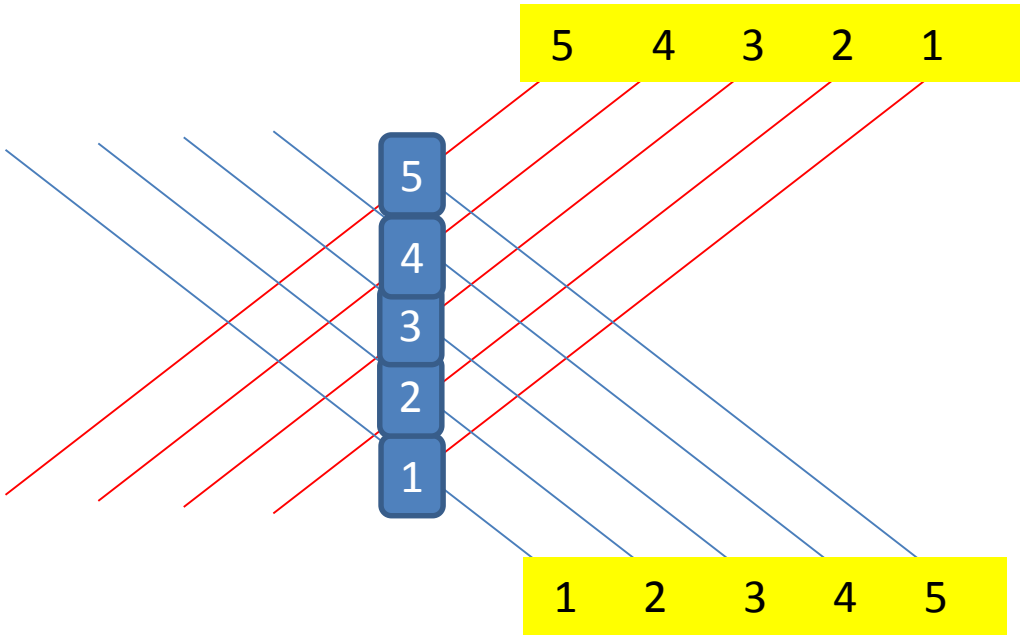
Block 1 is below block 3, left of 4, :::
A(bove)B(elow)L(eft-of)R(ight-of)
representation

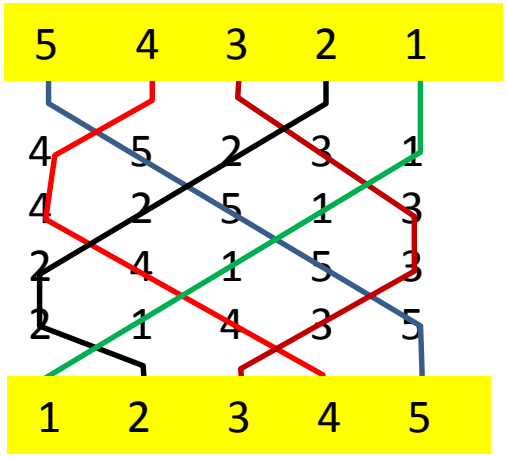
This is what a sequence pair (31524)(12345) represents

Extreme cases





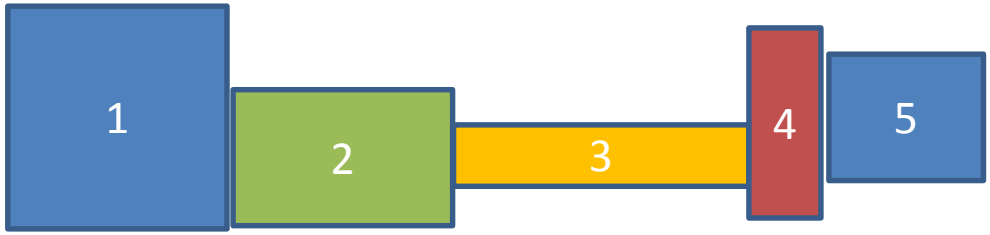




If Permutation I=(1 2 3 4 5) is defined "normal" or the "reference" or the "standard", other permutations convey certain information as:

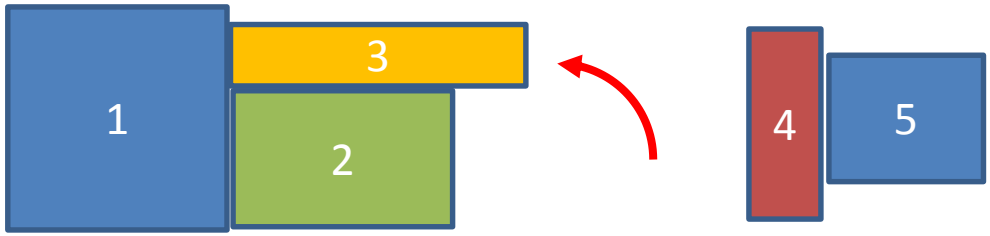
why (13245)? = why (3 2) reversed?

There is a "reason". The reason is the information which (13254) conveys.



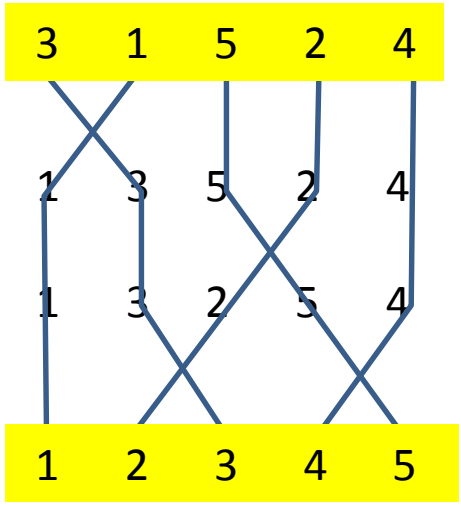
This is assumed normal corresponding to (12345).

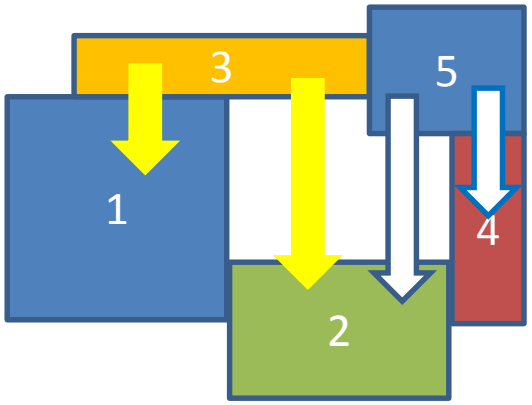
While, (13254) is not, 3 and 2 are in reverse.



3 is above 2.

The channel and the placement
that are of the same DNA (31524)





Any other topic
related to "PERMUTATION"?

How about a Nobel Prize topic?

Professor Shinya Yamanaka

2012 Nobel Prize by iPS cells
(Induced Pluripotent Stem Cells)

A cell that can be any.

iPS placement:

Background:
An incremental design goes in such a way that
first we find one initial solution and
improve the current solution incrementally.

However, it is not easy to find an initial solution.
Often, it is as hard as to get an optimum solution.

Various ideas, including well-known Lagrangean relaxation.

One strategy is as follows:

relax the constraint as we can find a feasible solution "easily".

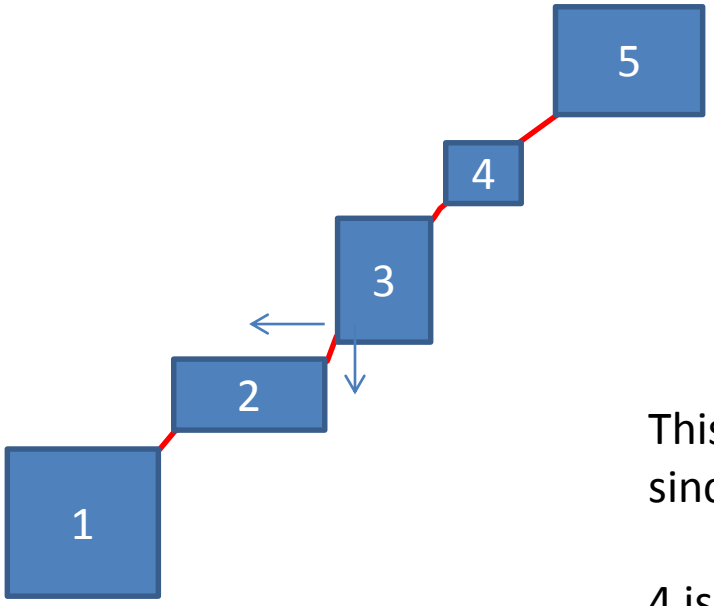
return the constraint slowly up to the full constraint.

Our problem:

Suppose the whole constraint is given by a sequence pair, say SP=(42513).

Our request : Give an image of the placement that satisfies SP.

This is the one that is requested.

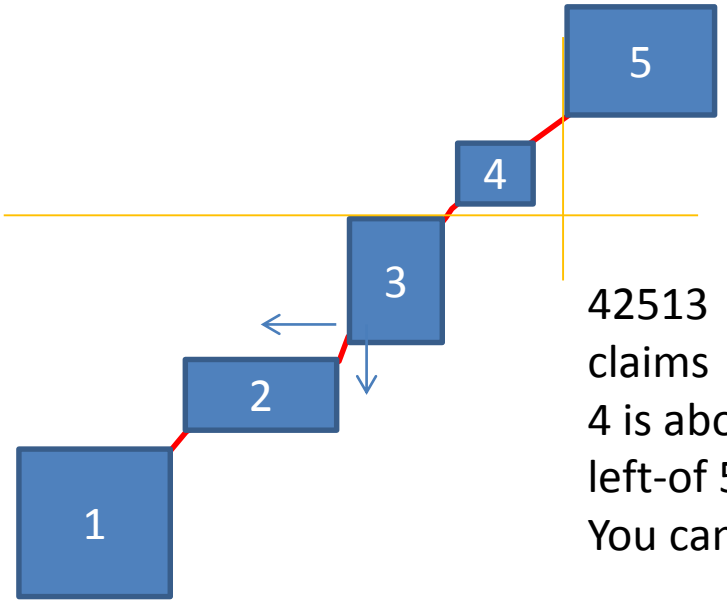


This scratch satisfies (42513)
since

4 is above 2, 1 and 3
4 is left of 5,
:::::
2 is above 1 and left of 5 and 3,
.....

This placement is iPS (Induced Pluripotent Stem) Placement.
It satisfies every permutation for ordered objects and
fixes its position according to individual specification
whatever it is.

According to (42513), block 4 is free inside a certain area.

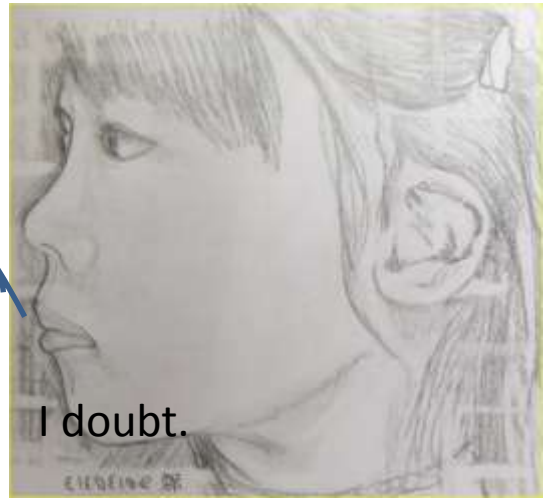


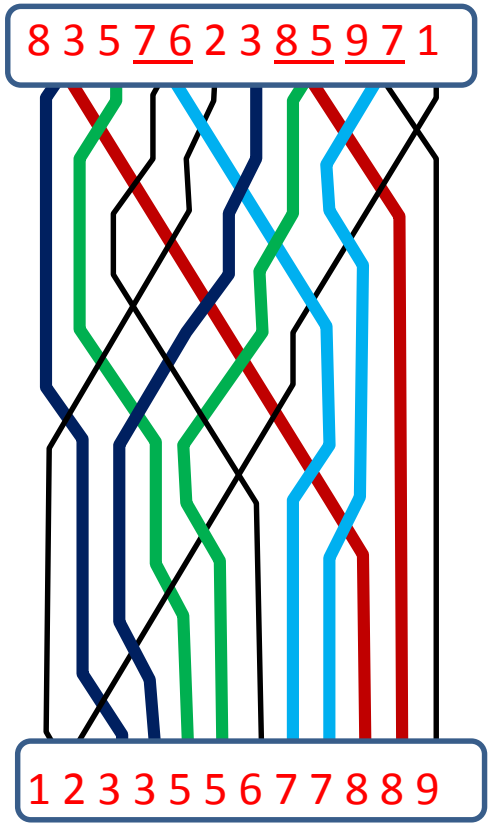
42513
claims
4 is above 2, 1, and 3, and
left-of 5.
You can choose the location by your request.

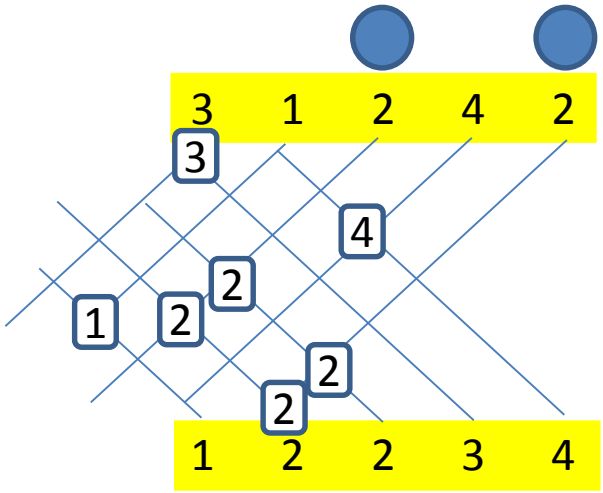
Label Repetition Problem

A permutation could be both channel code and placement code

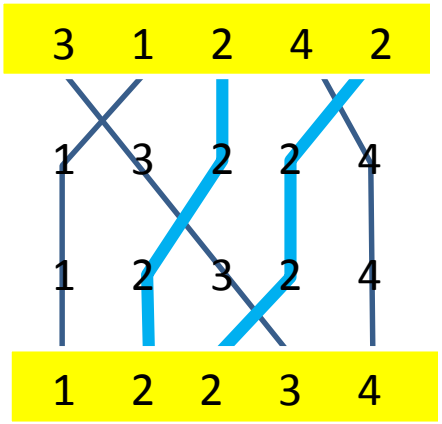
Is that right?
A channel allows repetition of labels.

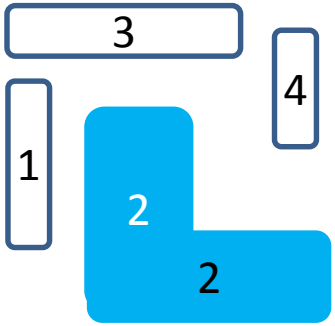



8 3 5 7 6 2 3 8 5 9 7 1
1 2 3 3 5 5 6 7 7 8 8 9



here are two boxes
on a line
of the same label.



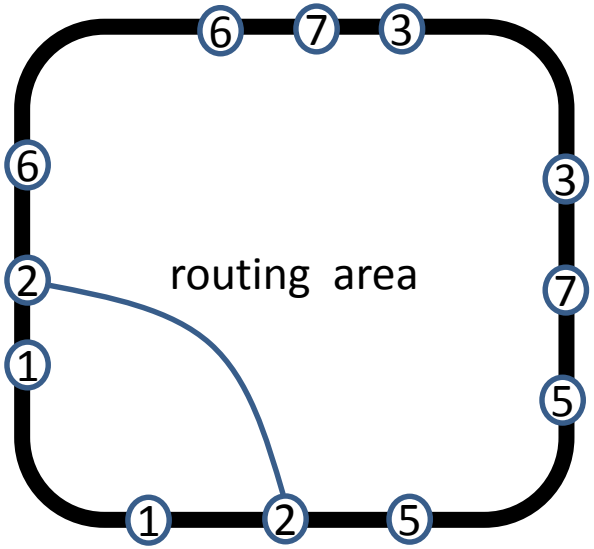


Each is independently placed
according to the ABLR relation,
but
they do not mind to overlap or not.

Please pardon me with mercy,
I have not yet spent
enough time on this.

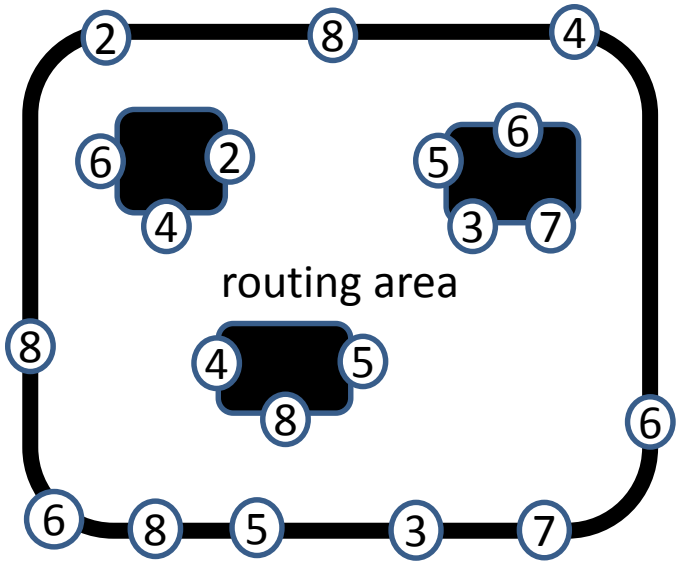
Go on to
"circular permutation and routing"

Can you say from the data of
circular permutation
(621125573376) if it is 100% routable?

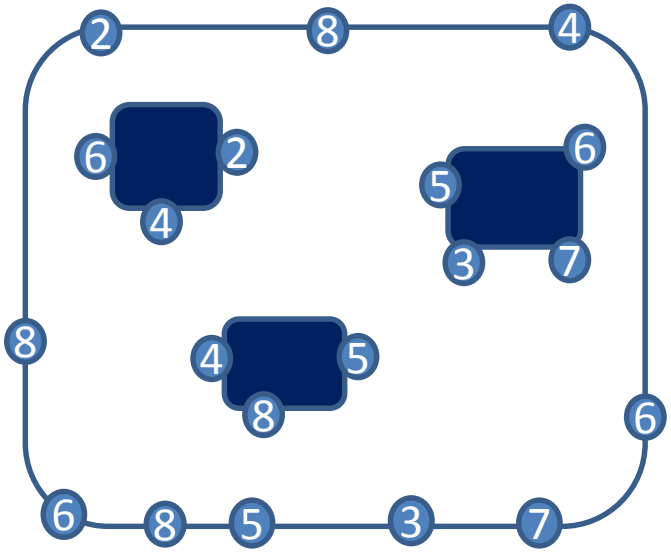


Yes, I do
by a linear time algorithm.

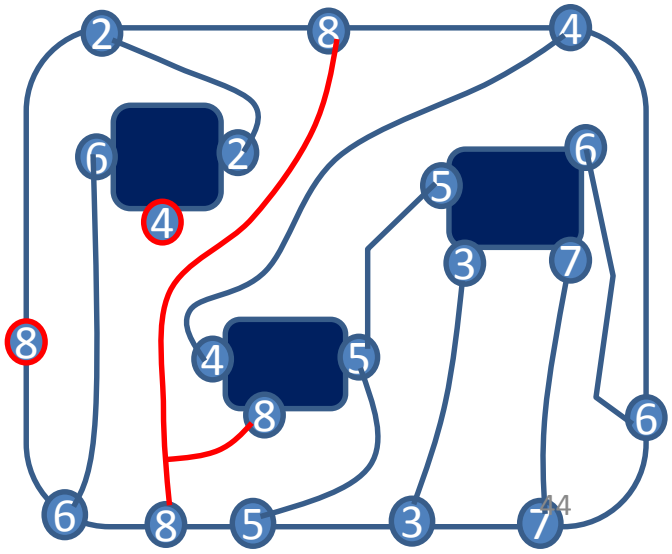
Can you say from the data of
the set of circular permutations {(624), (5637), (458), (2846735868)}
if it is 100% routable?



Yes, I do
also by a linear time algorithm.



I am not sure this is known or given an exact proof to the theorem.



Concluding

If labels (of the objects) are fixed,
any information is in the deviation from a certain reference order.

To think this way would be too rough or too impractical for EDA.

However, this is a mathematical fact.
We cannot escape the phenomena caused by this reason.

Permutation is a mathematical terms to handle the concept.

I think it is not rare when EDA problems are described
in a direct form in permutation.

Cross resolution is a typical example.

It was a surprise for me that Sequence-Pair had been buried in channel routing.

Channel routing was my CAD theme 33 years ago, and SP 23 years ago.

I could not notice this relation until I started to prepare for this talk which is also thanks to a surprise present honored by ISPD.

Sherlock Holmes remarks

"Not invisible but unnoticed, Watson."
"You did not know where to look, and so you missed all that was important."

You shall think deep

Look up the future.

End