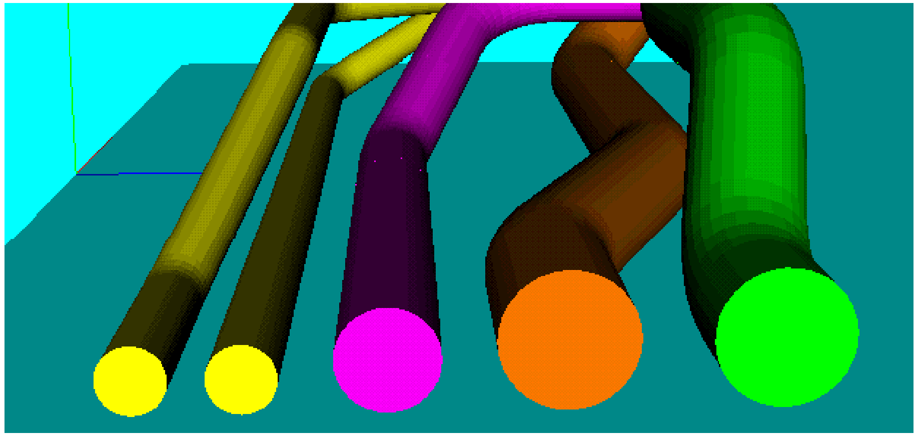
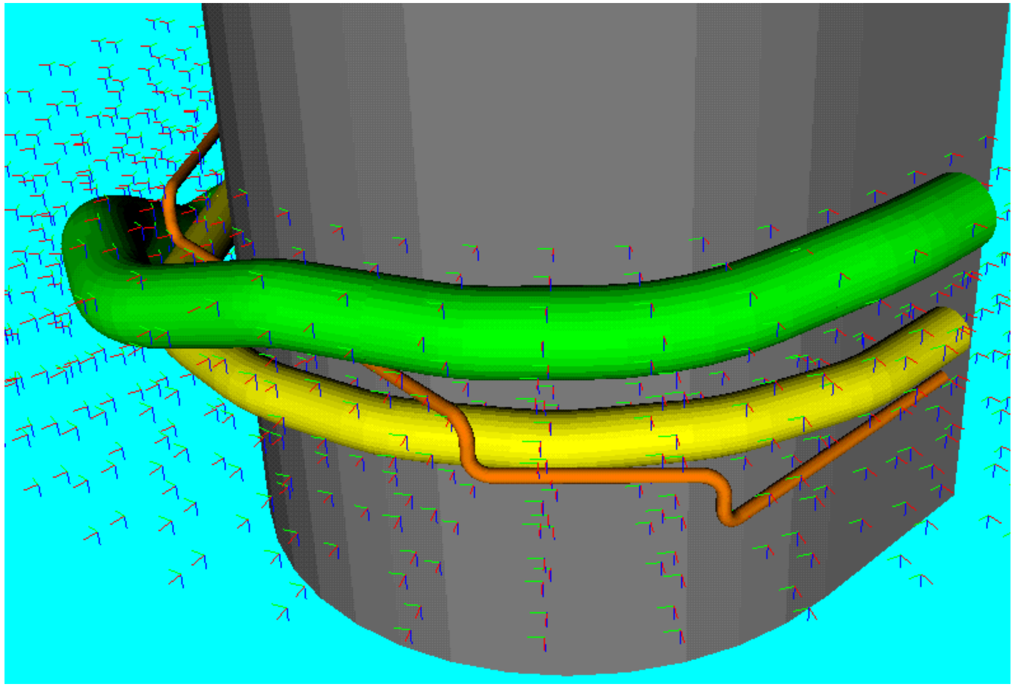
Automatic Piping Arrangement Design Considering Piping Supports and Curved Surfaces of Building Blocks





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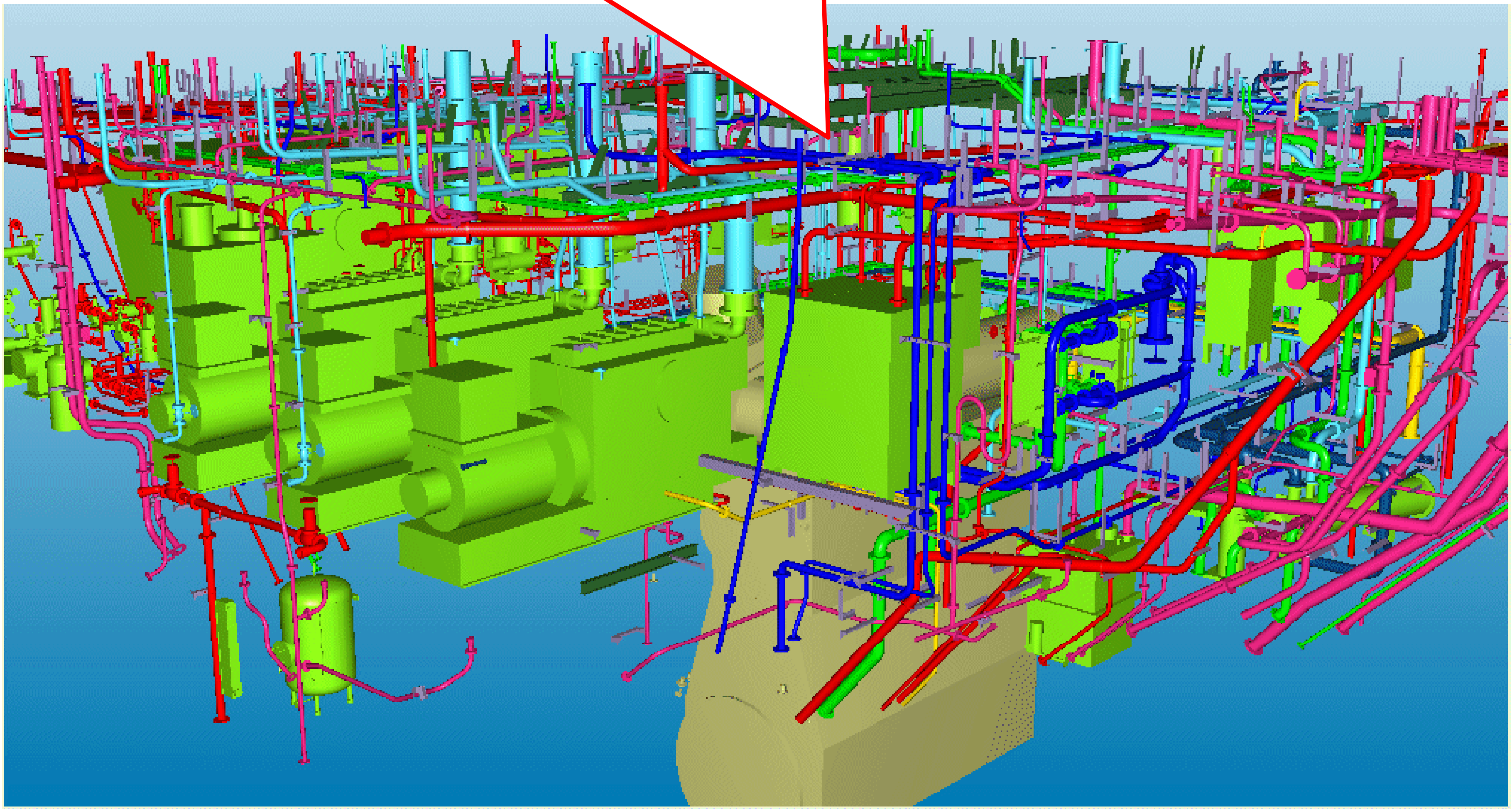
ICCAS 2017, 26-29 September 2017, Singapore

Motivations

3D-CAD systems reduce human efforts,



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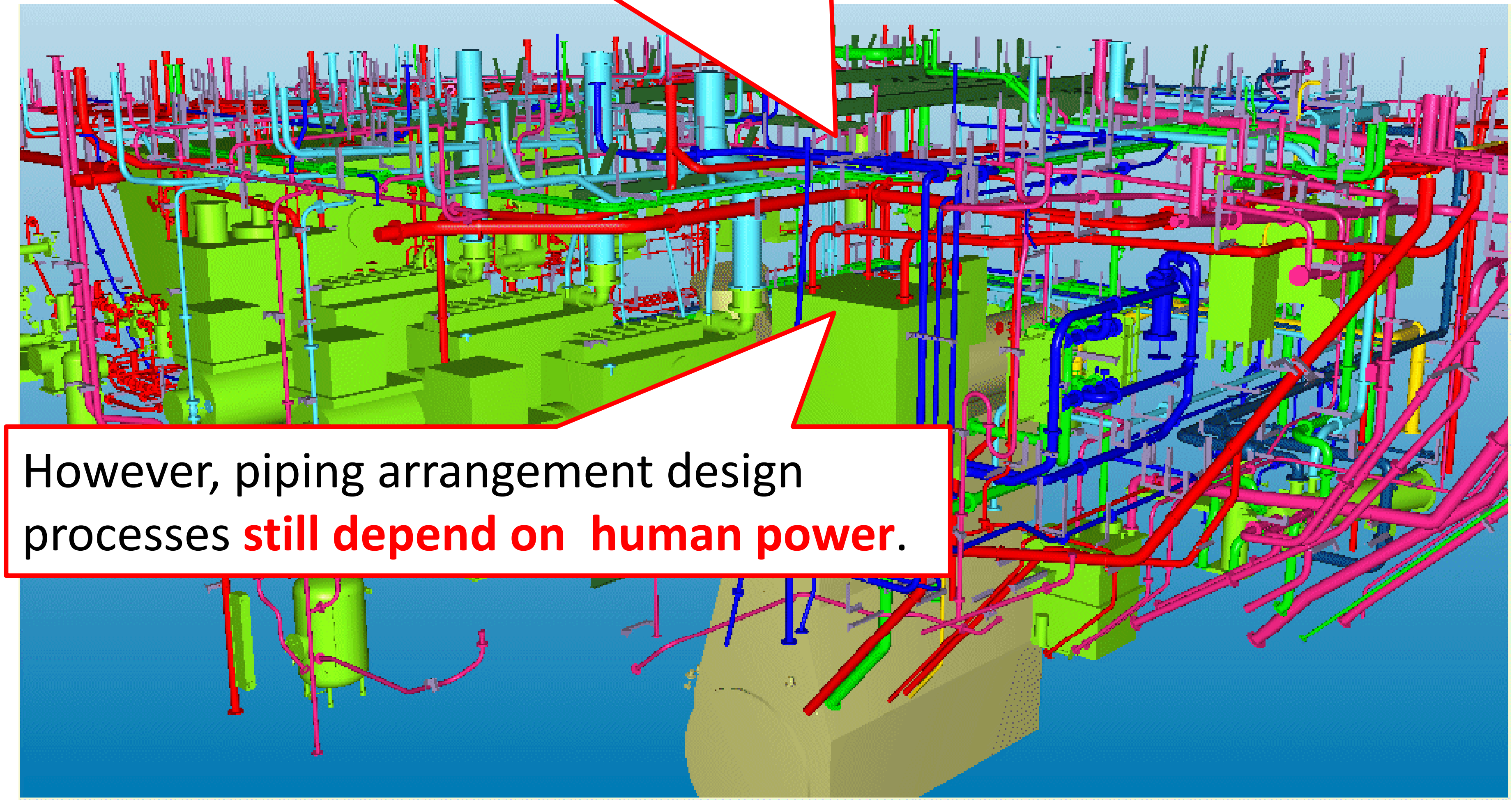

However, piping arrangement design processes **still depend on human power**.

Motivations

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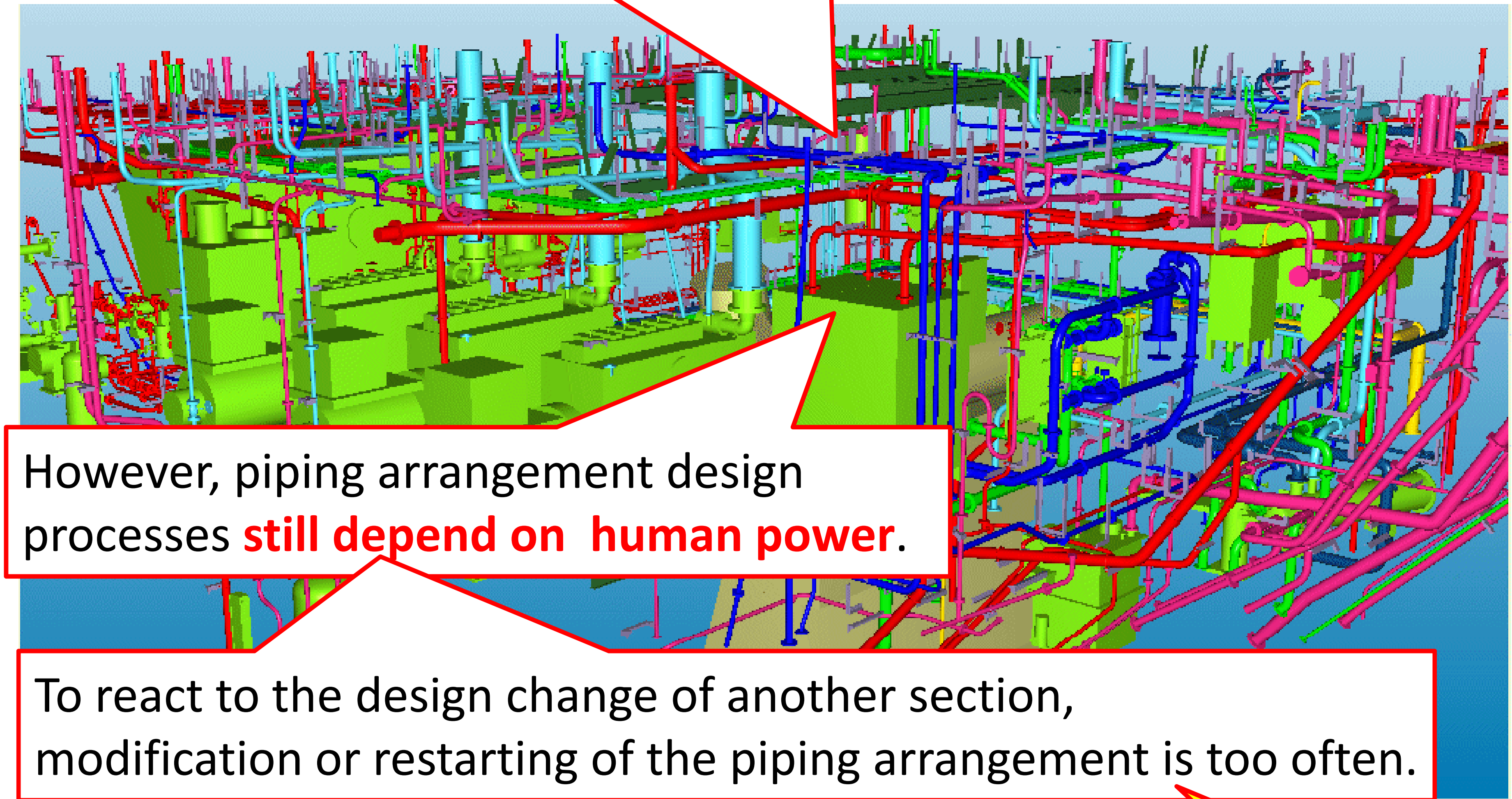


However, piping arrangement design processes **still depend on human power**.

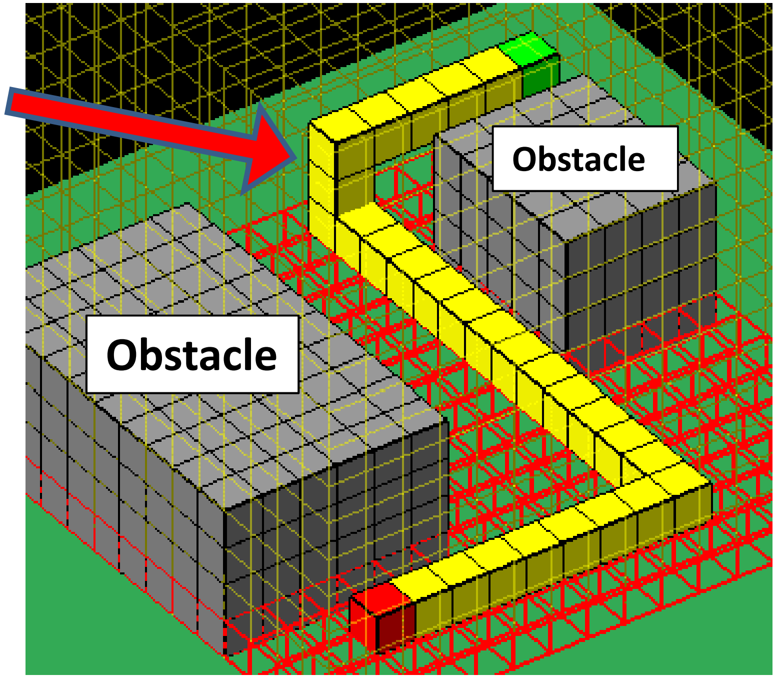
To react to the design change of another section, modification or restarting of the piping arrangement is too often.

It is torture for the designers!

Automatic Piping arrangement Design system will save more time and money!

Conventional Regular-Grid Approaches

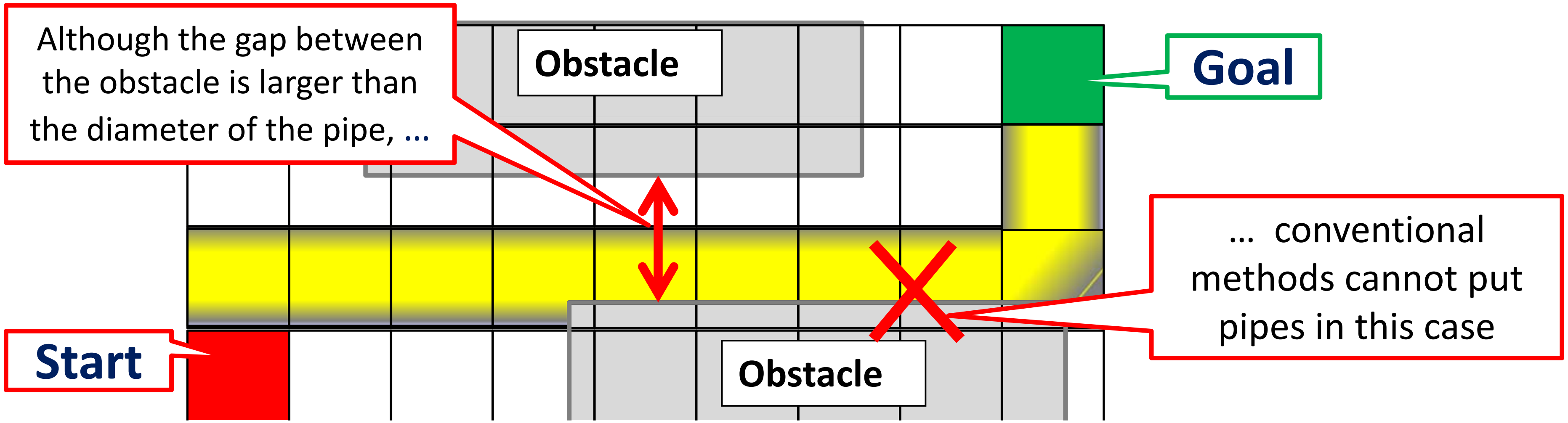
◆**The target design space is divided into regular grids where the mesh size is lager than the pipe's diameter.**
◆**The grid world is translated into a weighted graph.**
looking on the pipe arrangement problem as <u>a routing problem</u> in the weighted graph



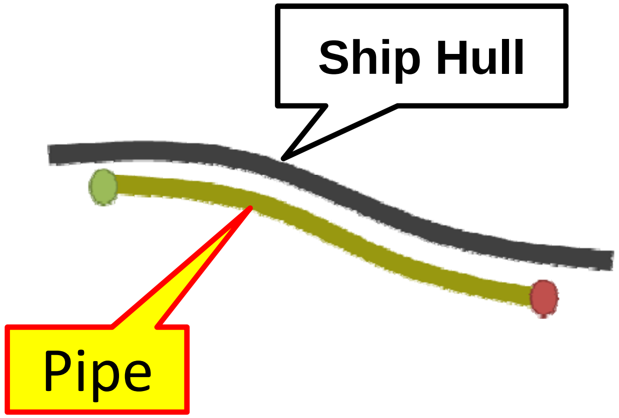
solved by "**Dijkstra's method**"

Disadvantage is …

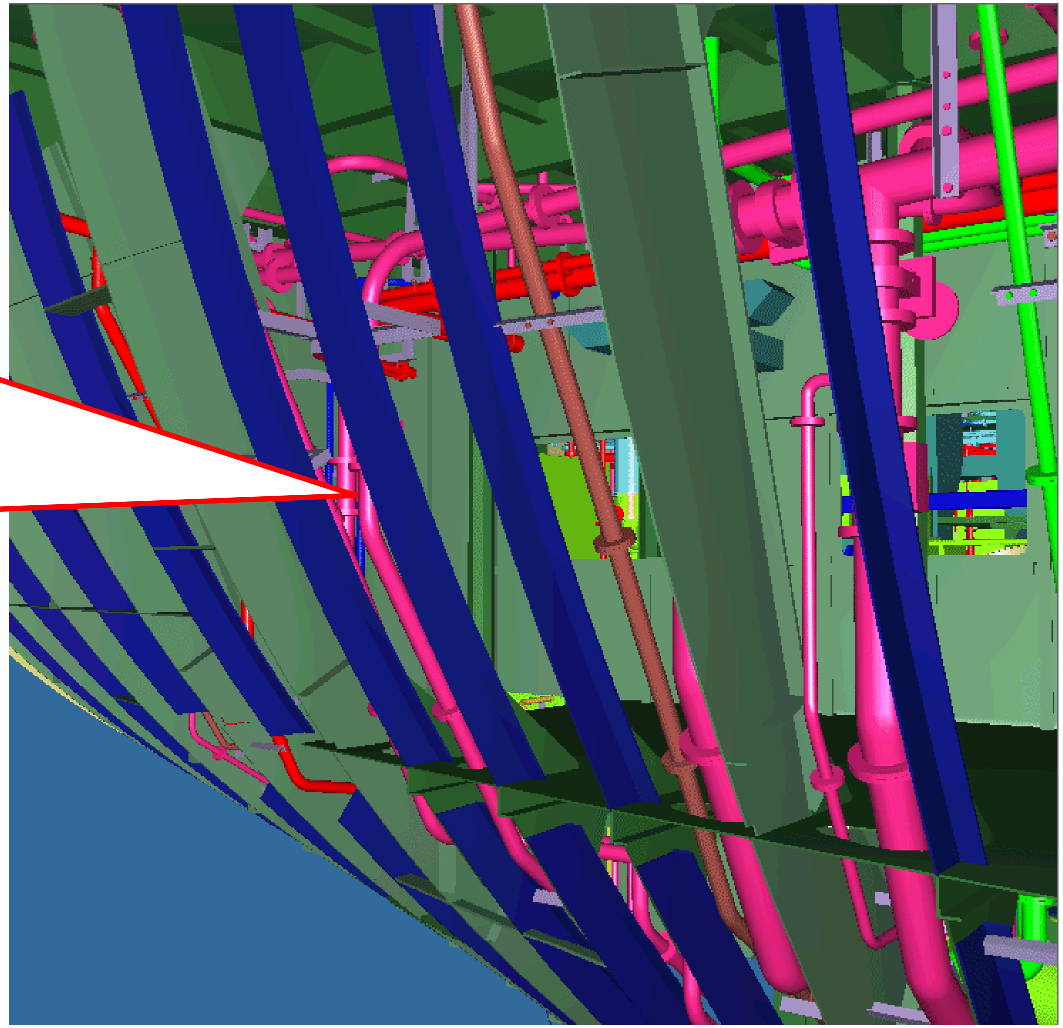
× **The mesh size is restricted to be larger than a pipe's diameter**
× **Directions of the pipes are restricted along XYZ axes.**

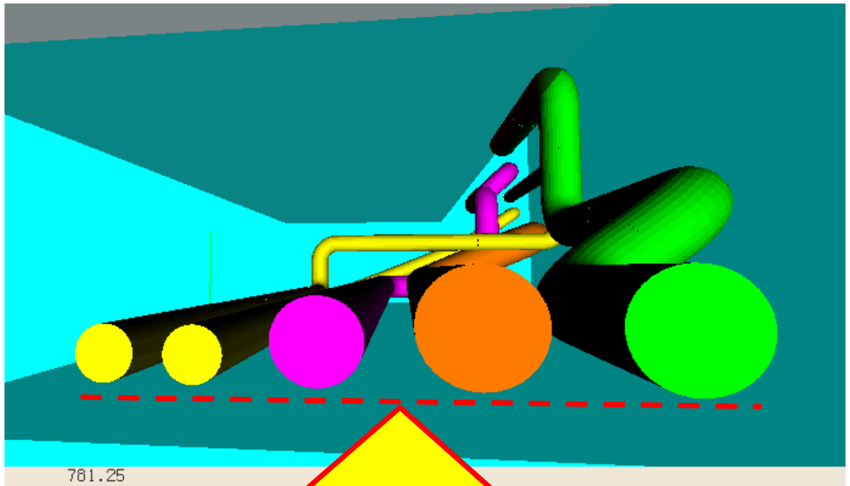


Regular grid methods cannot consider in the following situations:



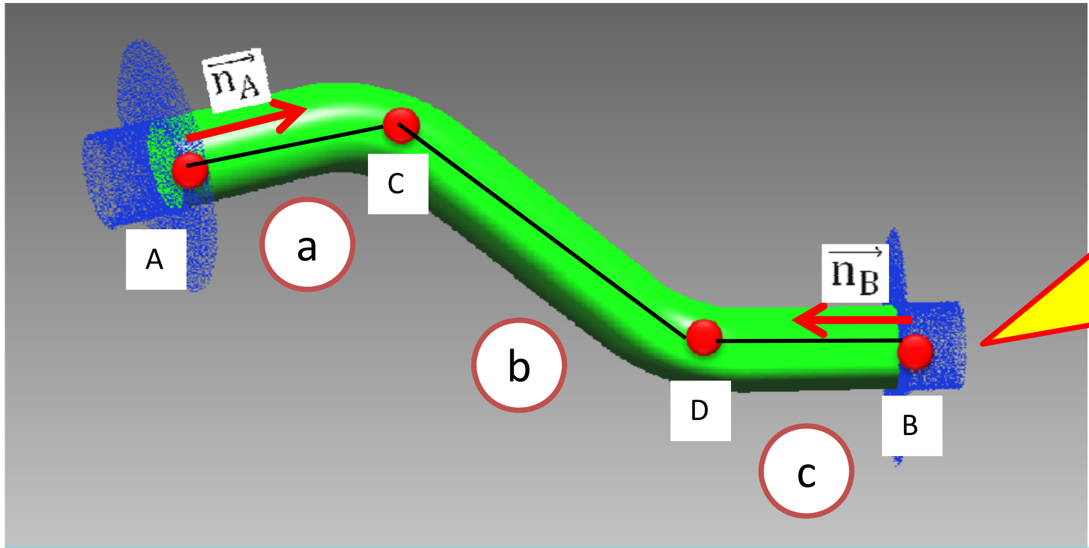
Pipes are often arranged along the curved ship's hull.



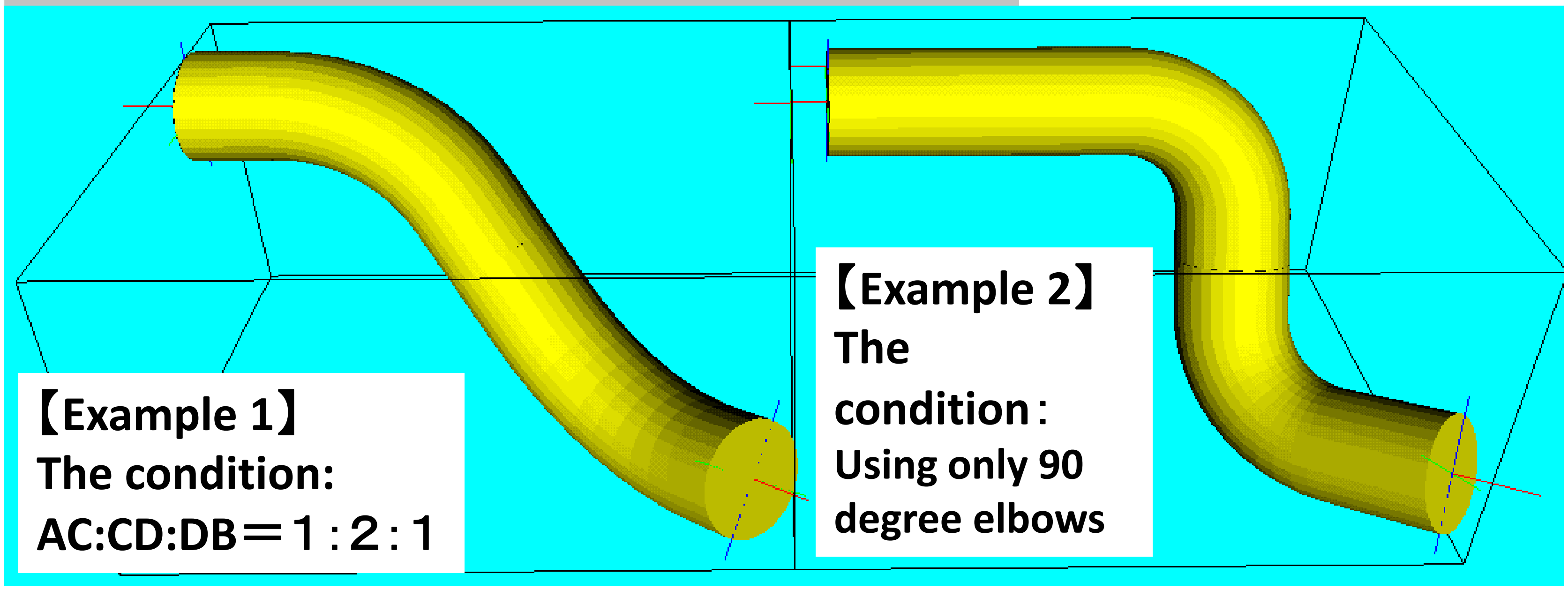


Pipes are arranged so as to make use of the same support in the different pipes.

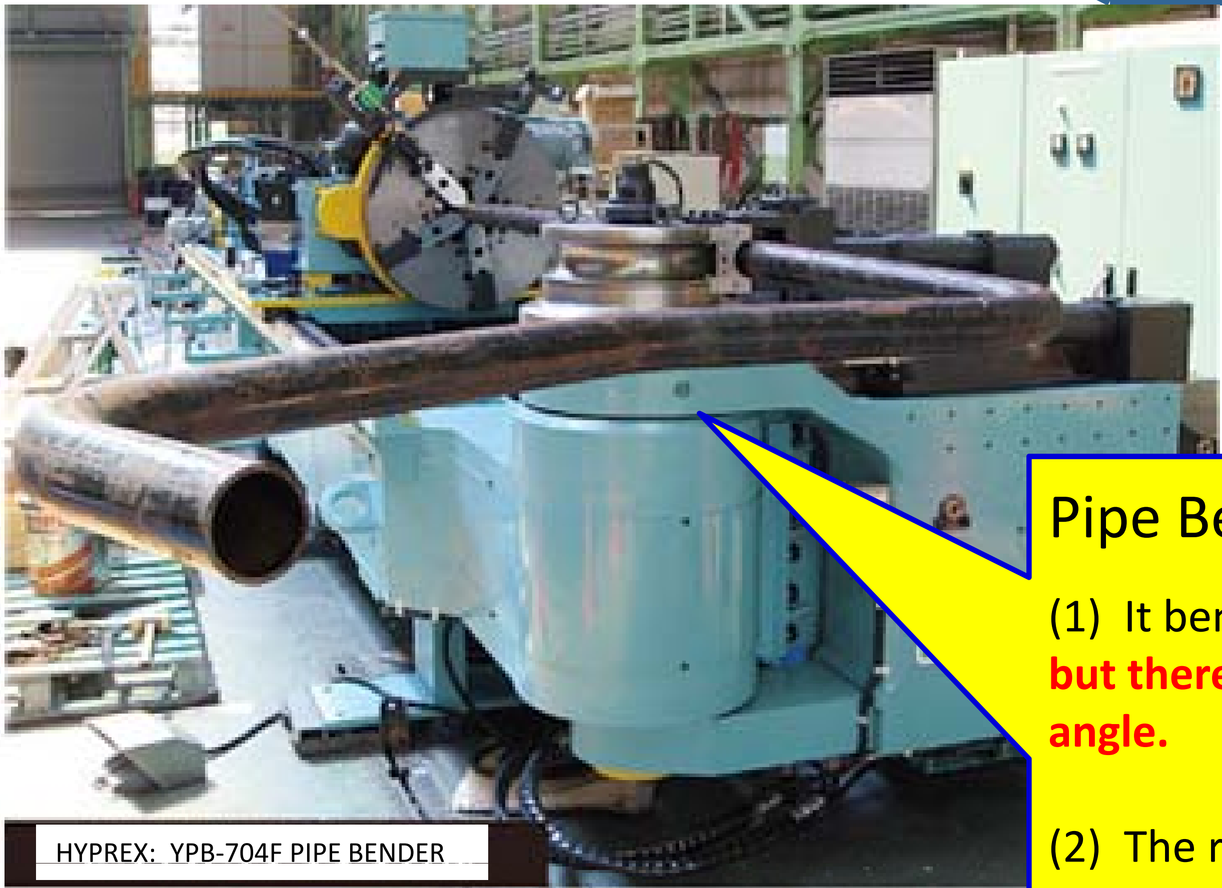
Preparation to overcome the defects of Regular Grid Methods



Geometrically, all the pipes with two bends can connect arbitrary two design points which have positions and directions!



Constraints of the real pipe's shapes



Pipe Bender：

(1) It bends pipes with arbitrary angles, **but there exists a limit of a maximum angle.**

(2) The radius of the bend is constrained by the pipe bender's molds.

(3) When it bends pipes, **straight parts between the bend are required to grasp the pipe.**

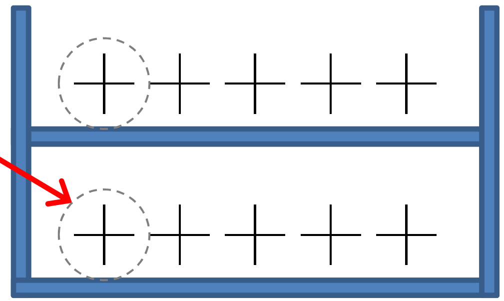
These troublesome constraints prevents automatic piping design!

A new approach to automatic design of piping

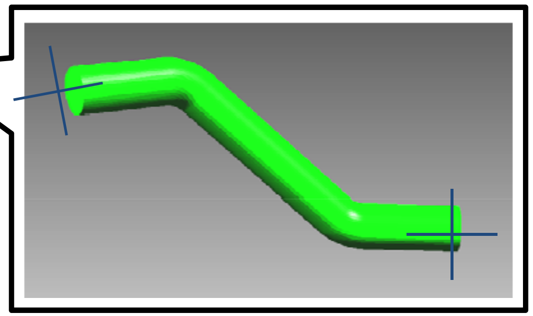
In actual piping design, the pipes are put the position that is certain distance away from structures.

If the pipes are put in the middle of the target design space, it is burdensome to arrange piping supports!

1） At all the position of the supports, put **design points** which indicate **position** and **direction** of the way of the pipe for each pipe.

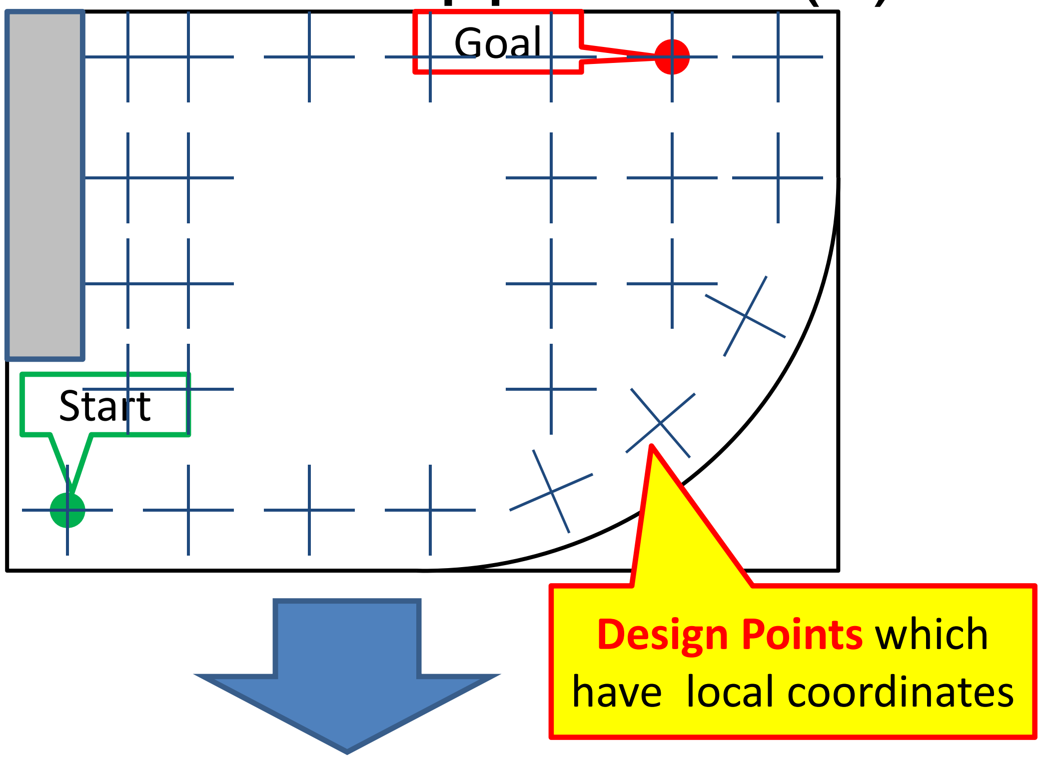


2） Make a weighted graph checking all the pair of design points which can connect by a pipe with two bends that can make using the pipe bender.

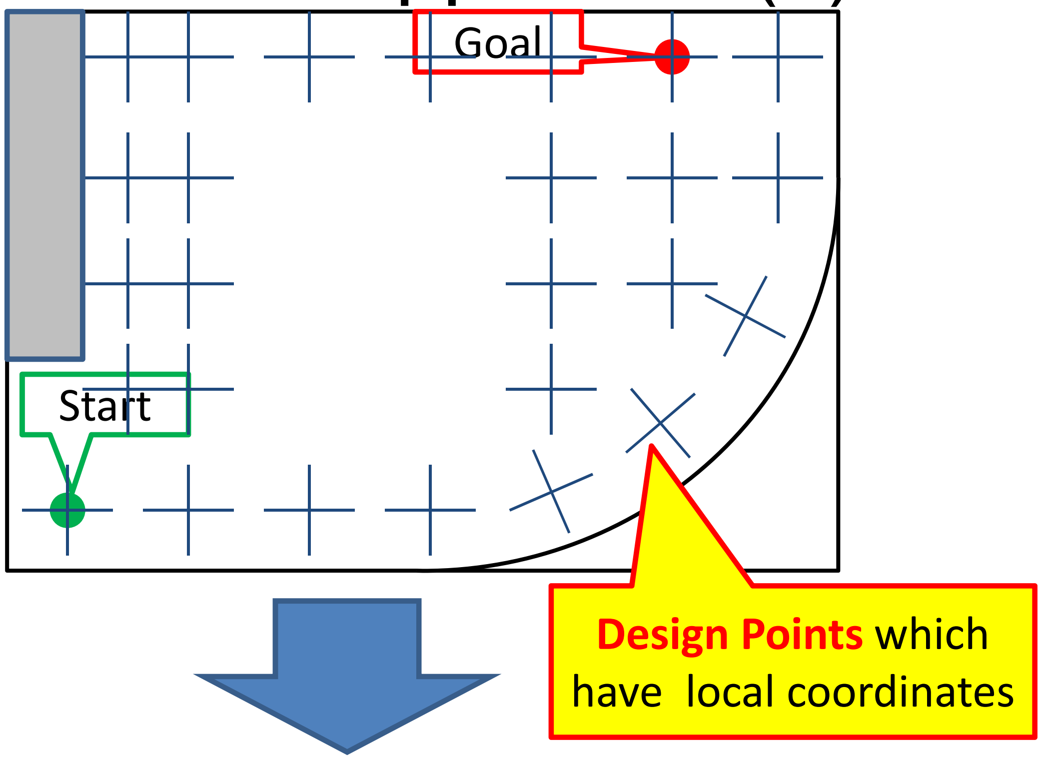


3） Generate piping path using a shortest path search algorithm in the weighted graph.

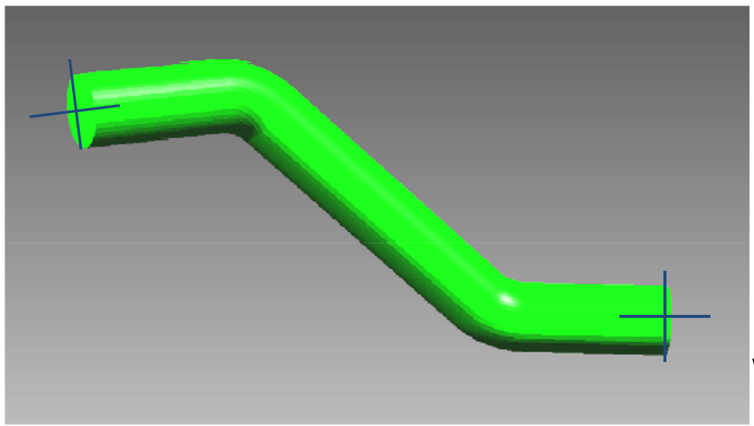
The new approach: (1) Putting Design Points



The new approach: (2) Making a weighted graph



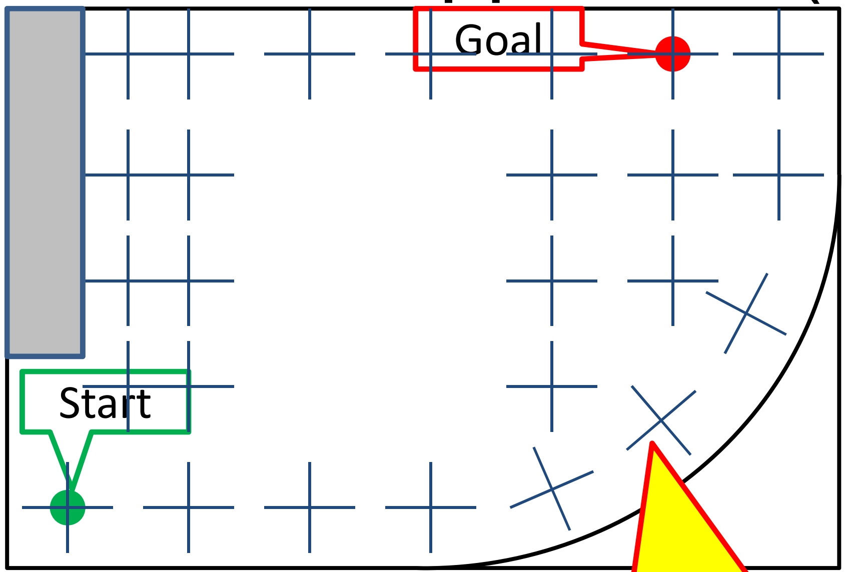
Design Points are connected by pipes which have two bends along the axes of the local coordinates.

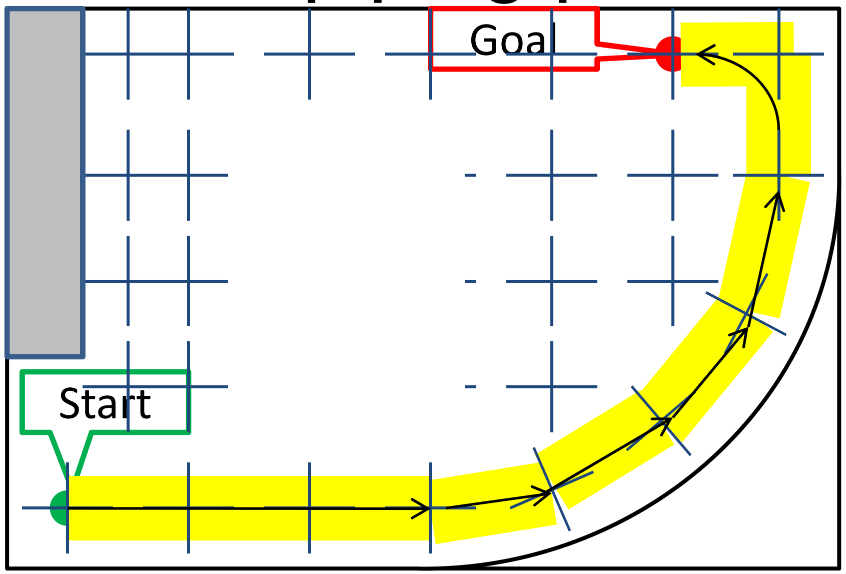


Weighted Graph

Shortest path Search
In the graphical network

The new approach: (3) Generate piping path

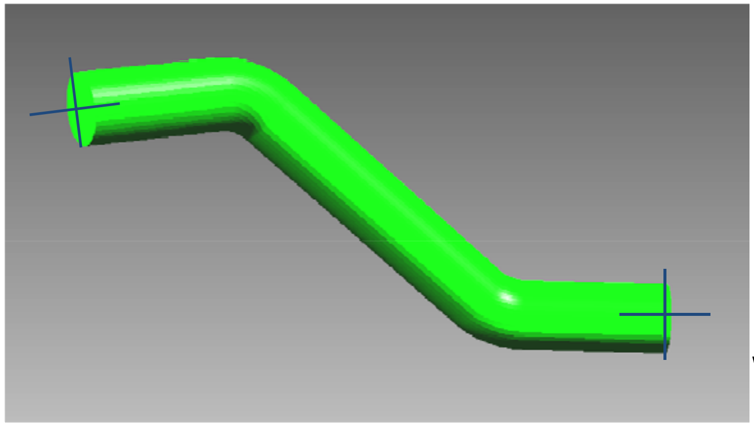




Design Points which have local coordinates

Pipe Arrangement

Design Points are connected by pipes which have two bends along the axes of the local coordinates.



Weighted Graph

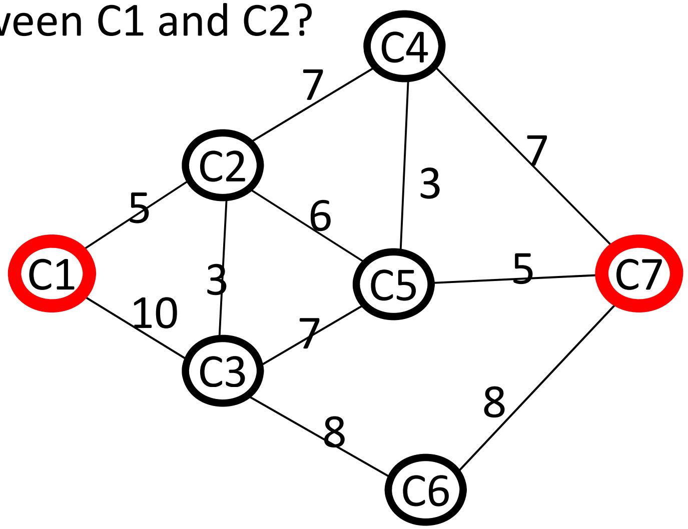
Shortest path Search
In the graphical network

Dijkstra’s Method

This method can …

- **find the shortest path in a directed and weighted graph**
- **guarantee a path with minimum costs**

Where is the path with minimum costs between C1 and C2?



The answer is …

Dijkstra's Method

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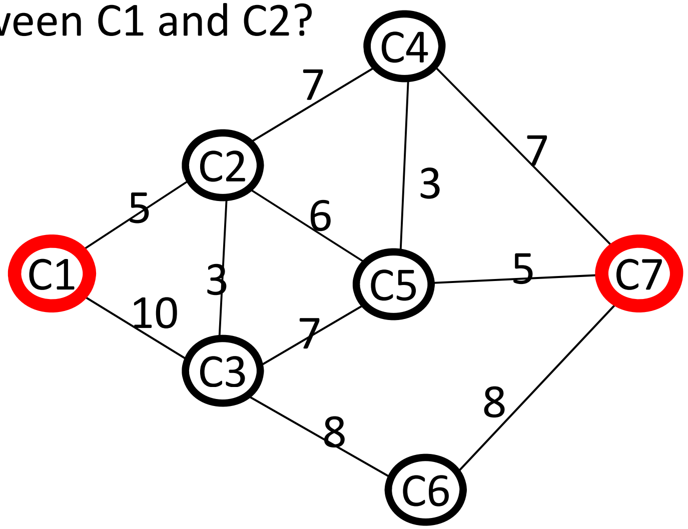

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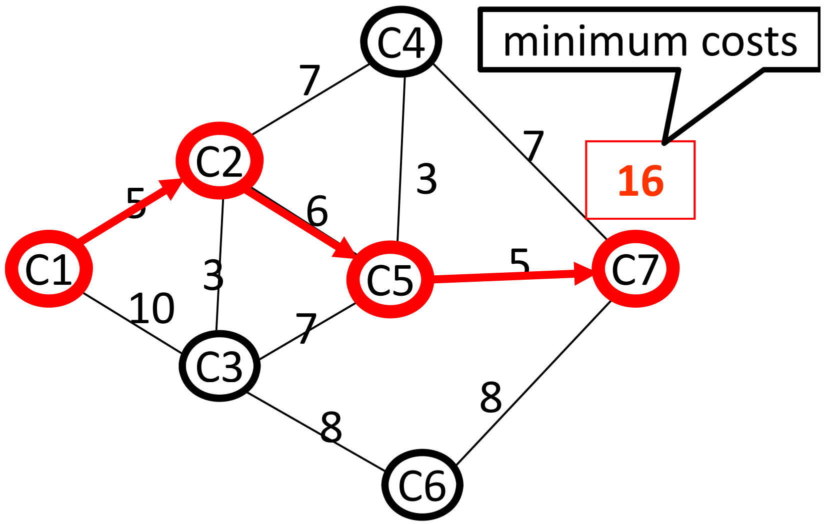
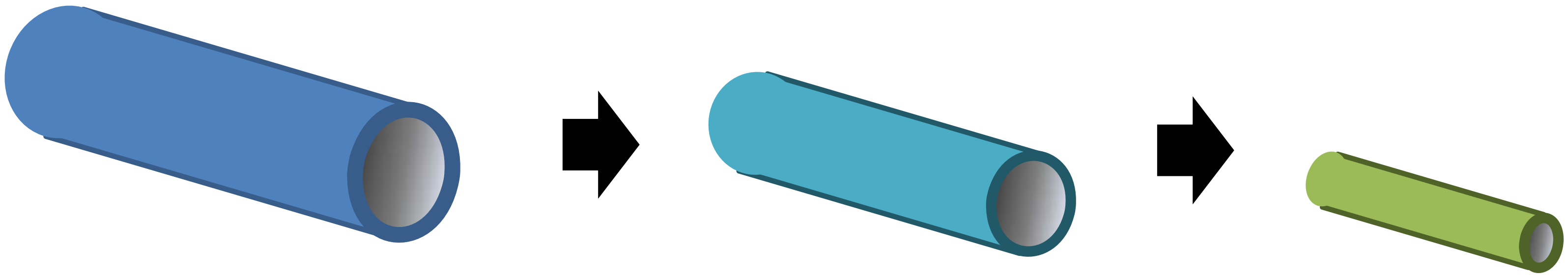
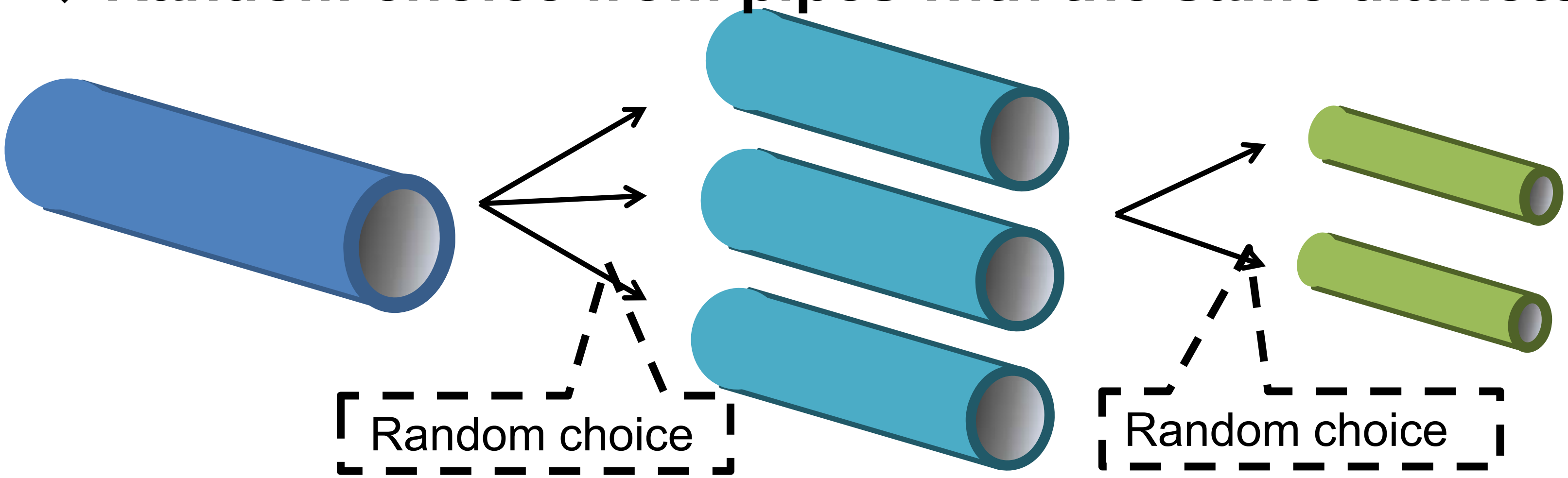


Multiple Pipe Routing

◆ **From the largest diameter to the smallest diameter**

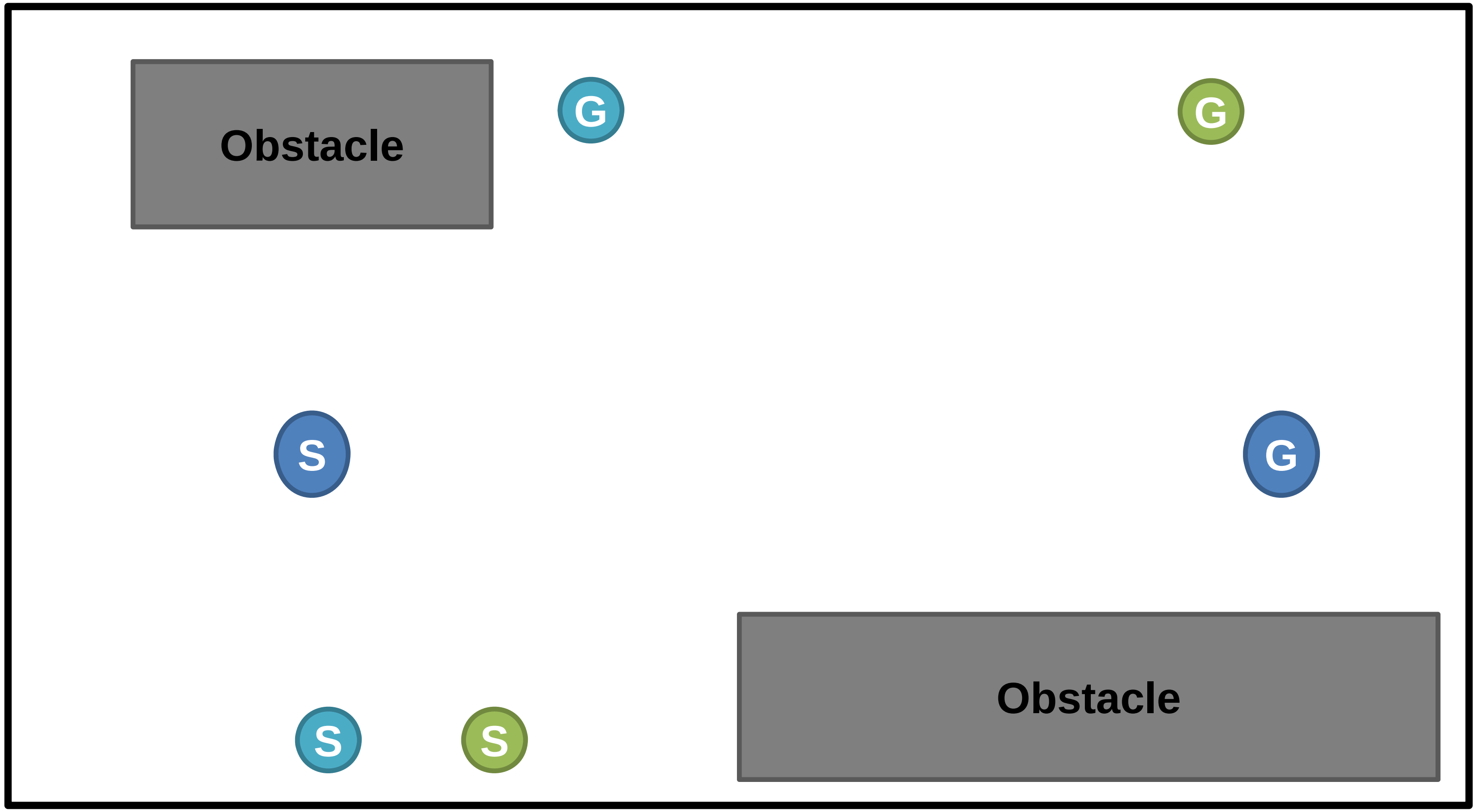


◆ **Random choice from pipes with the same diameters**



Order of Routing

Order of routing in real arrangement = **<u>From the largest to the smallest</u>**



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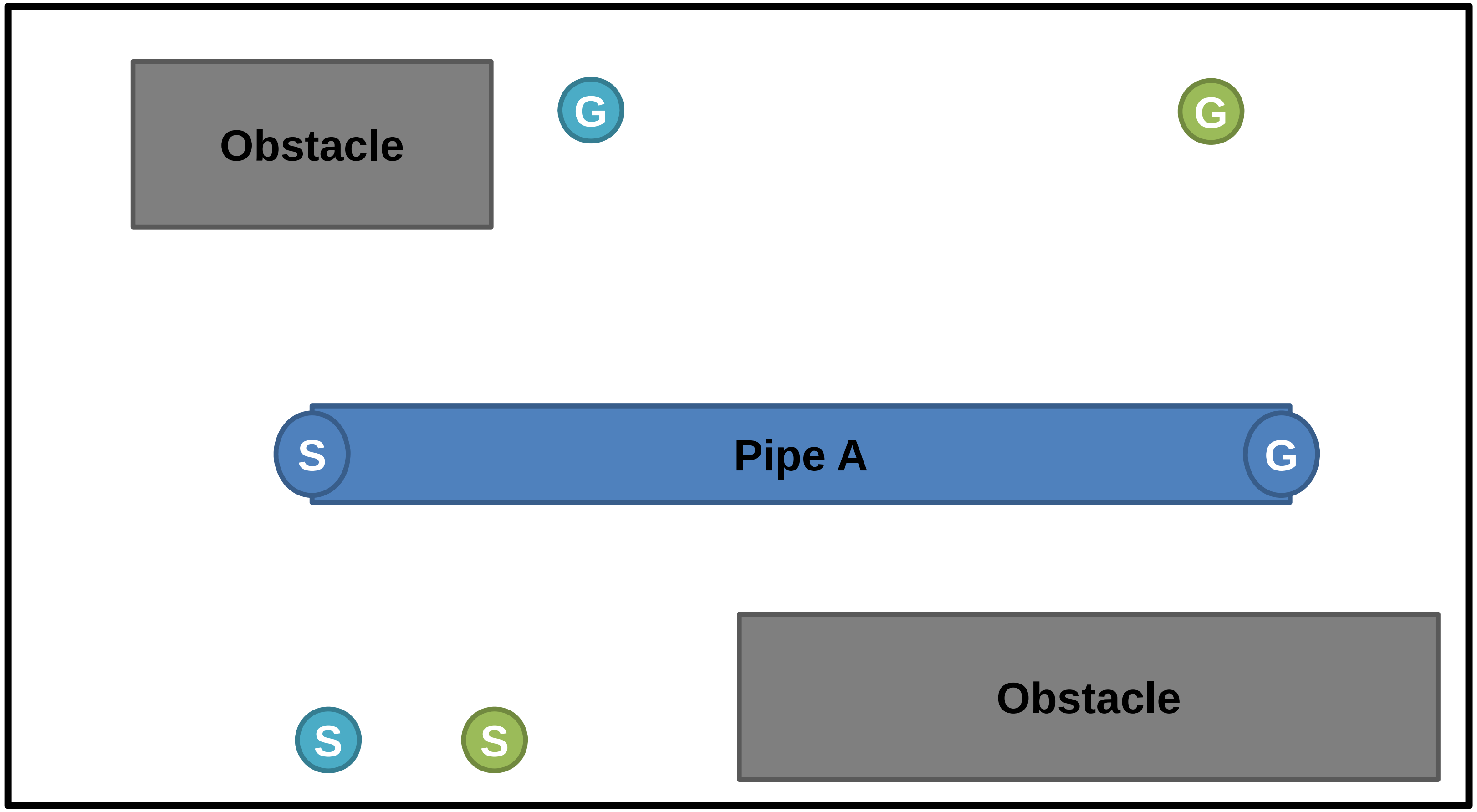

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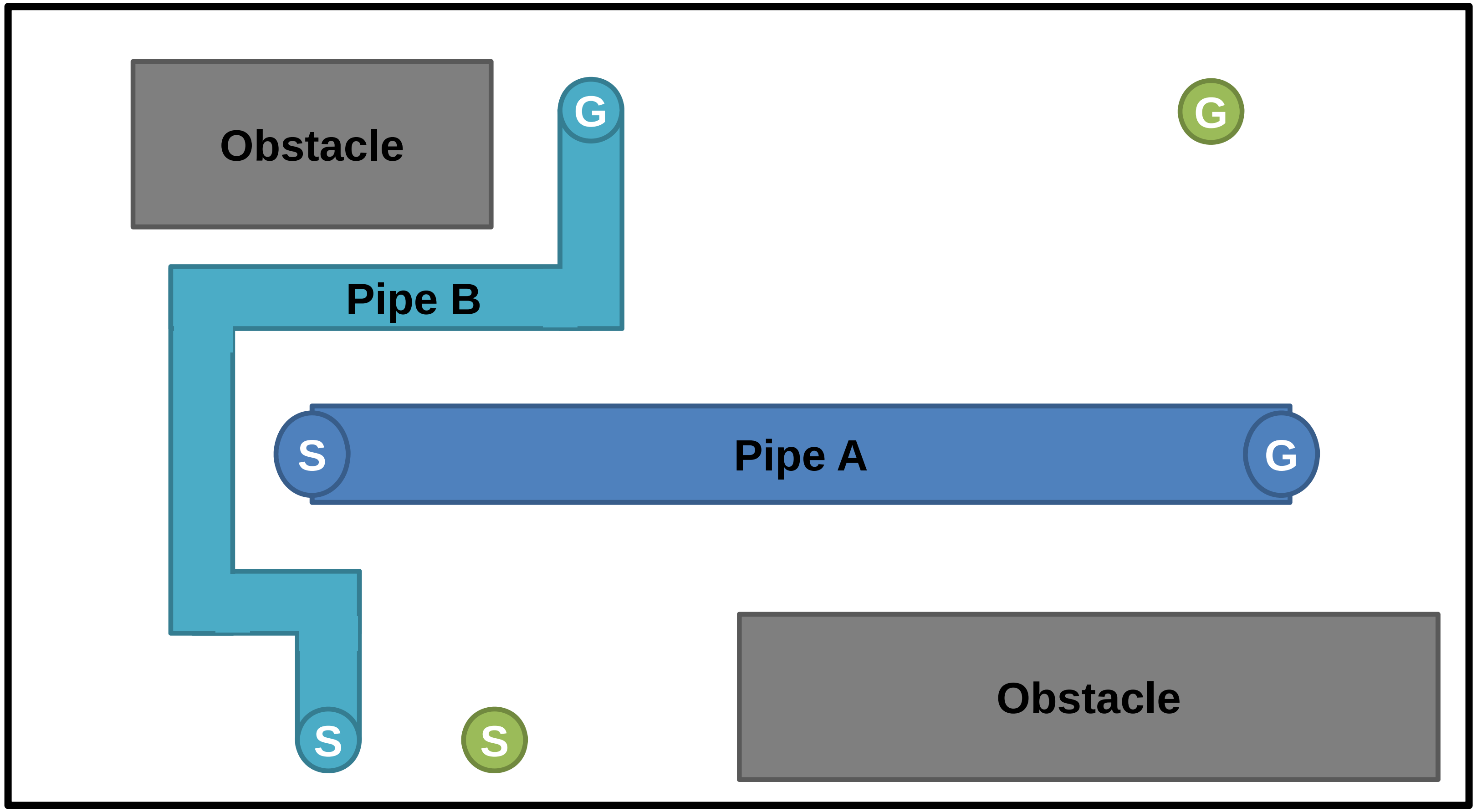

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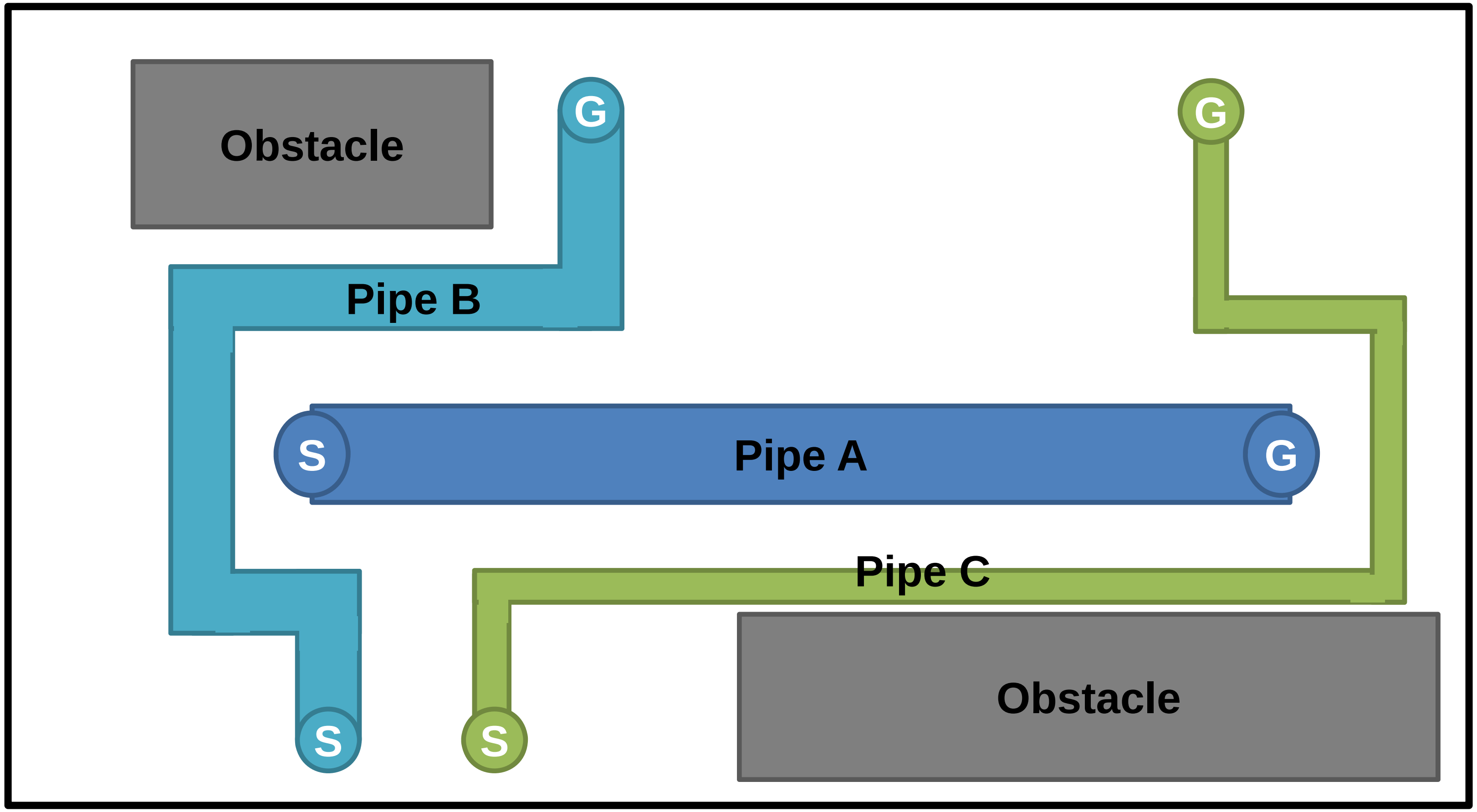
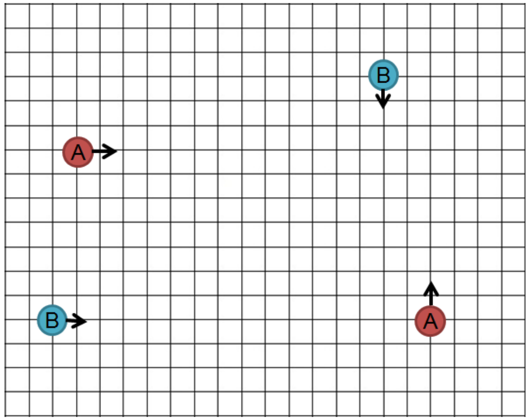


Largely different solutions depending on the order of arranging pipes



$\Phi_A = \Phi_B$

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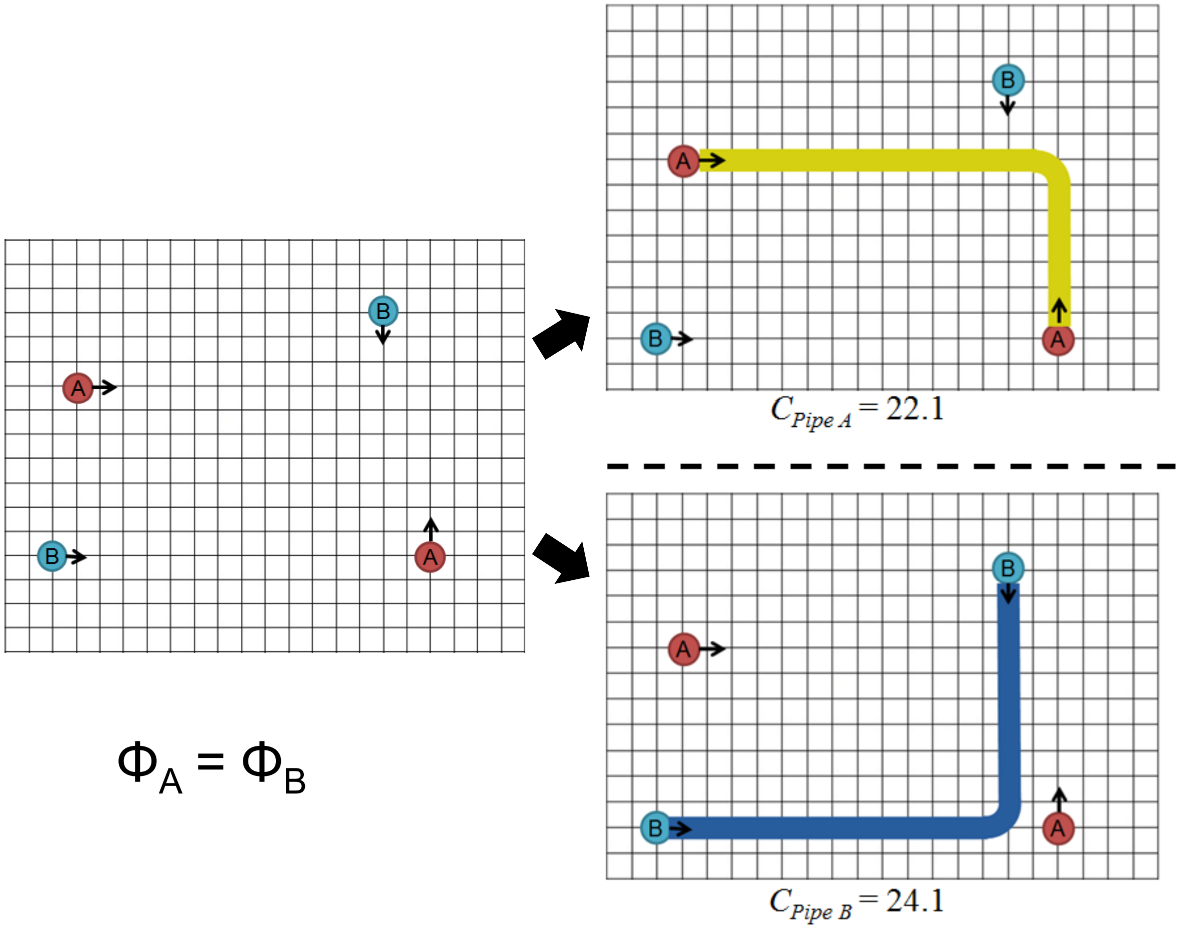

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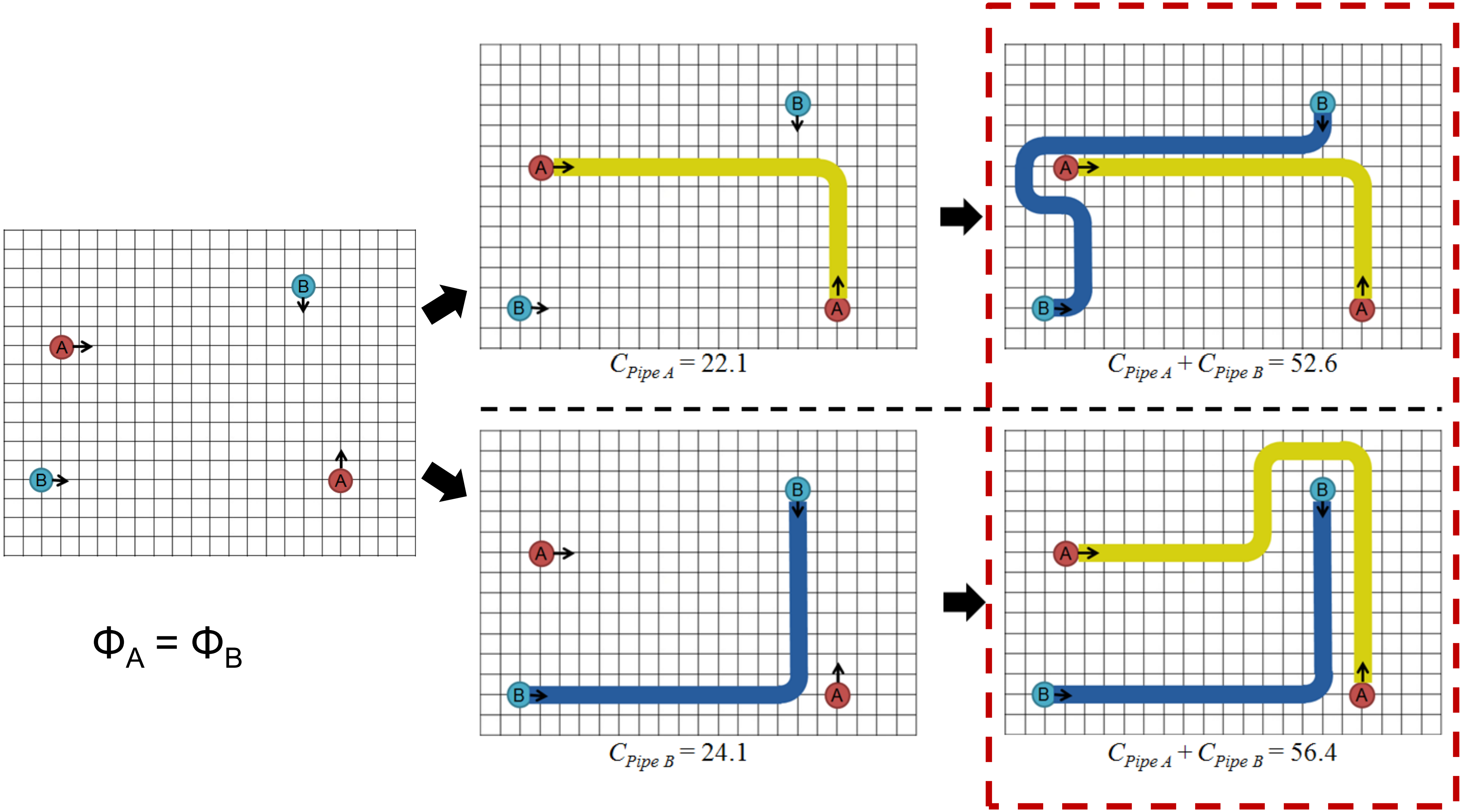

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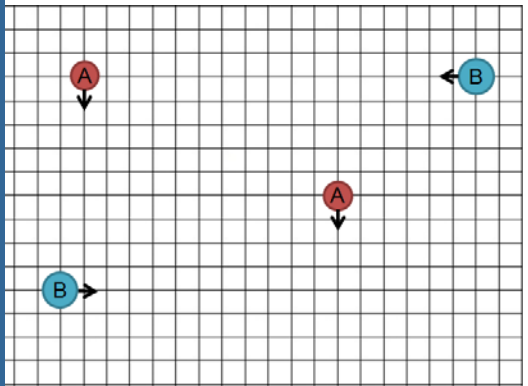
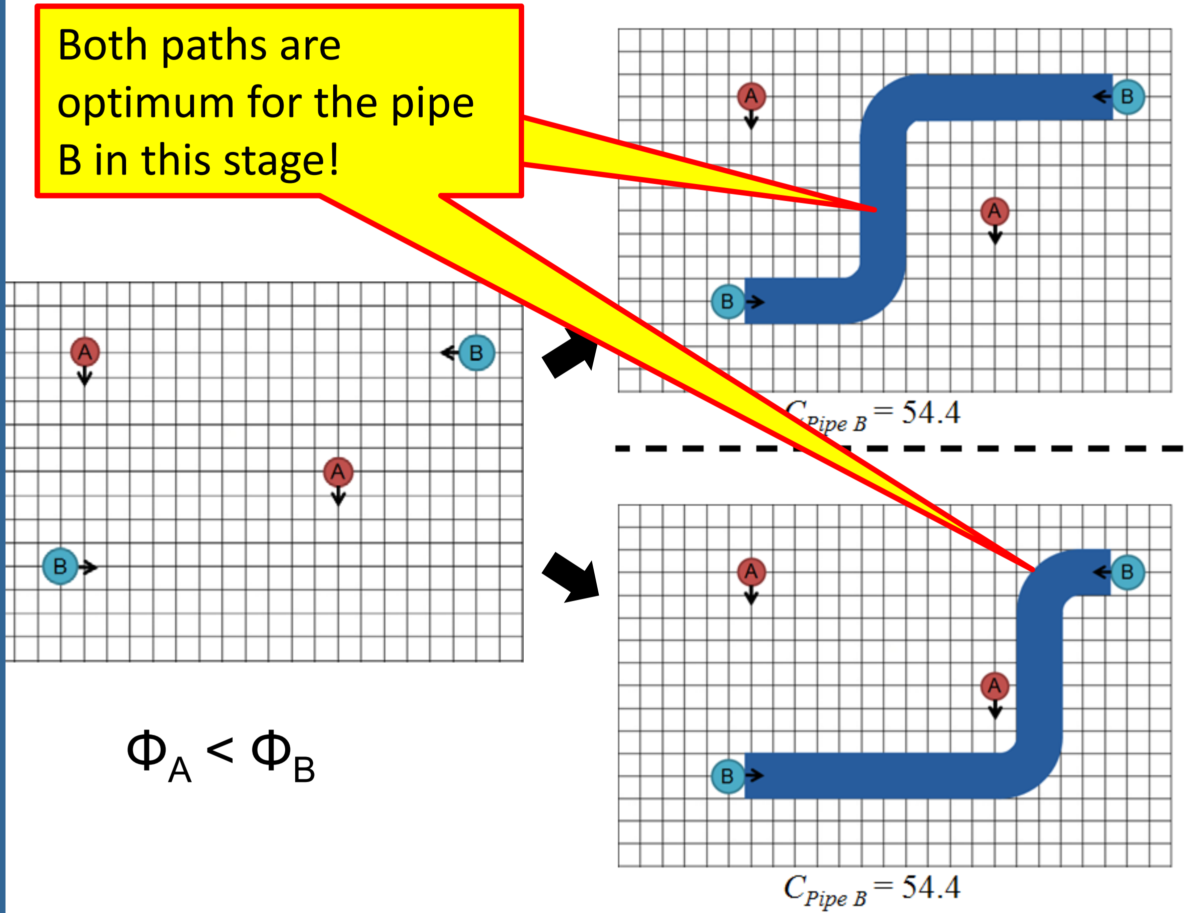
Path selection of one pipe



$\Phi_A < \Phi_B$

<u>Optimum Paths for one pipe are multiple,</u>
<u>But we cannot find the best for the other pipes.</u>

Path selection of one pipe



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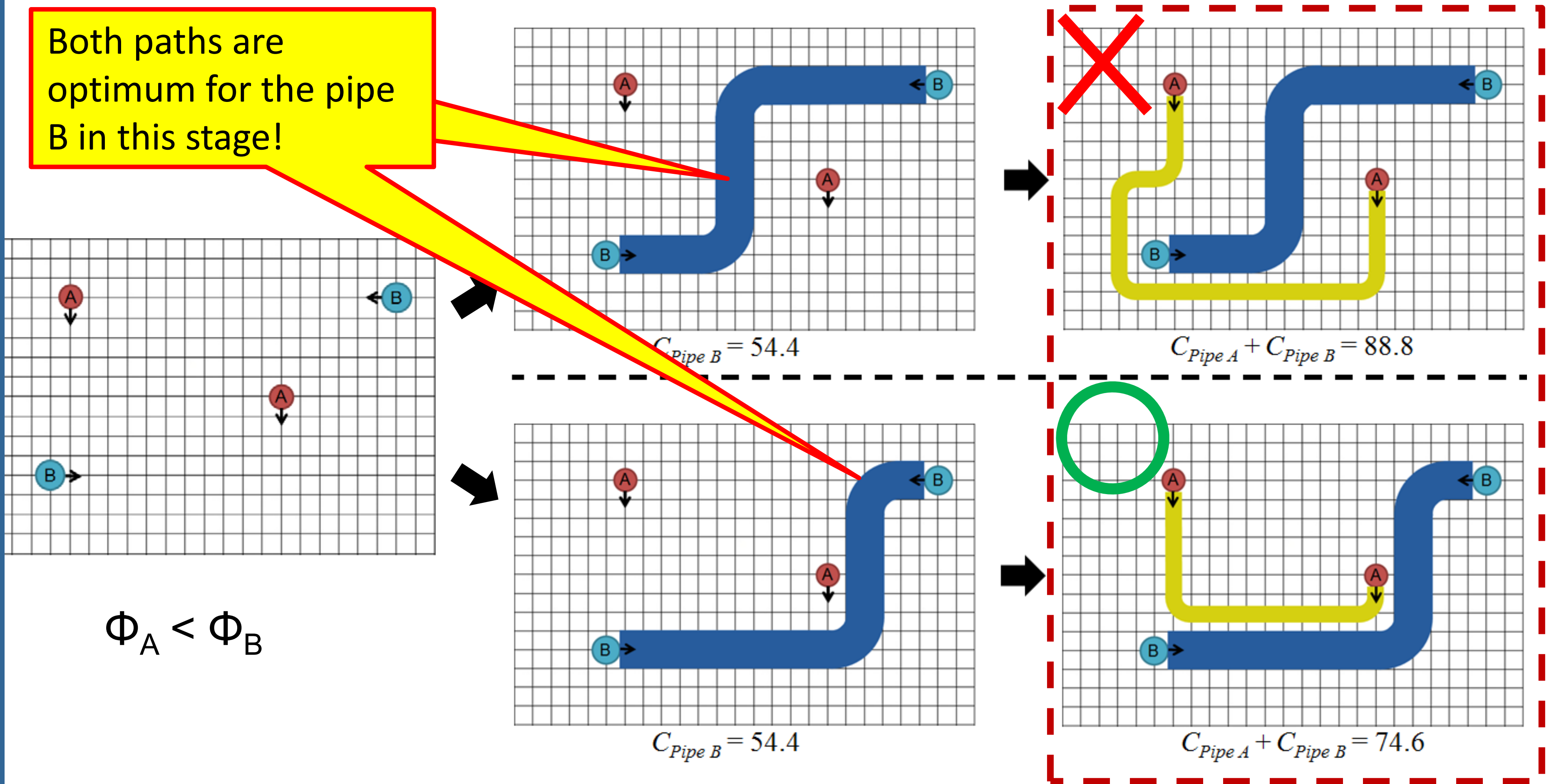

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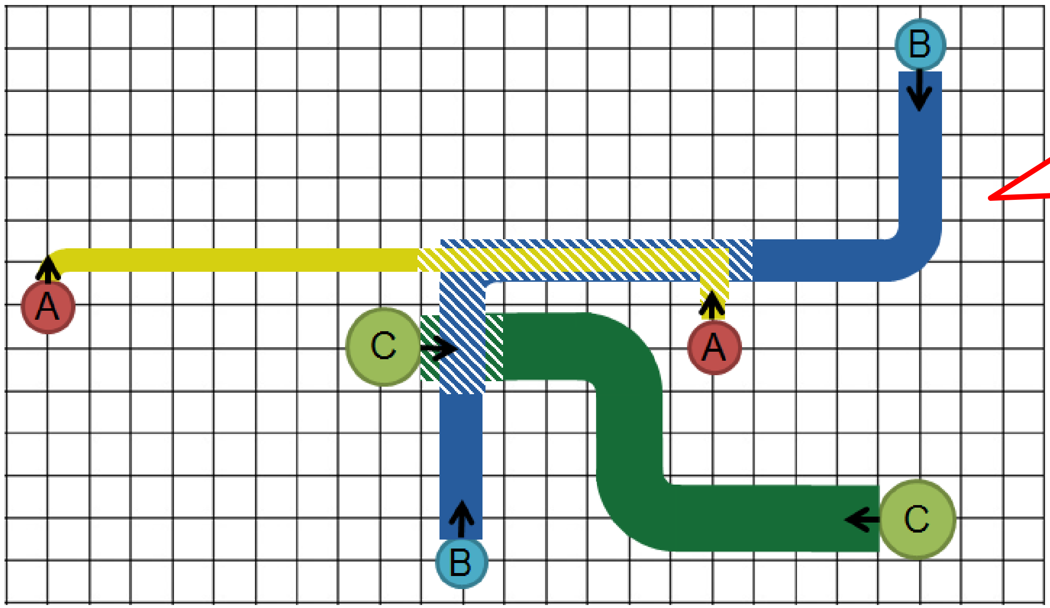
Interference avoidance of multiple pipes

Touch and Cross Method:

It is for a wire routing method for electronic circuits.



First, the system arranges the shortest pipes without considering interferences.

Approach: Interference avoidance of multiple pipes

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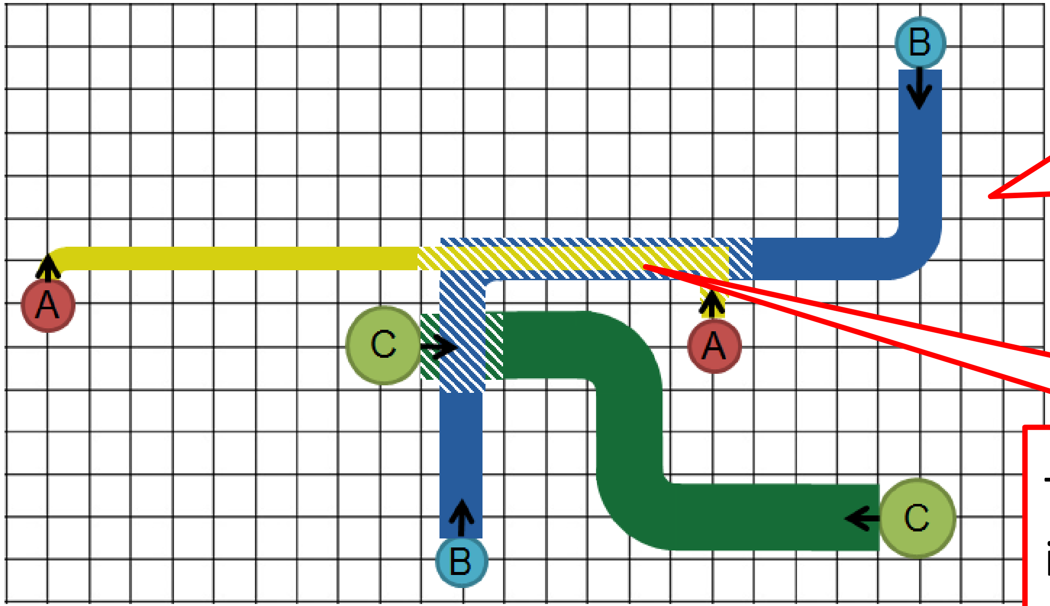

First, the system arranges the shortest pipes without considering interference.

Then, the system can acquire information about the **crowding area**.

Approach: Interference avoidance of multiple pipes

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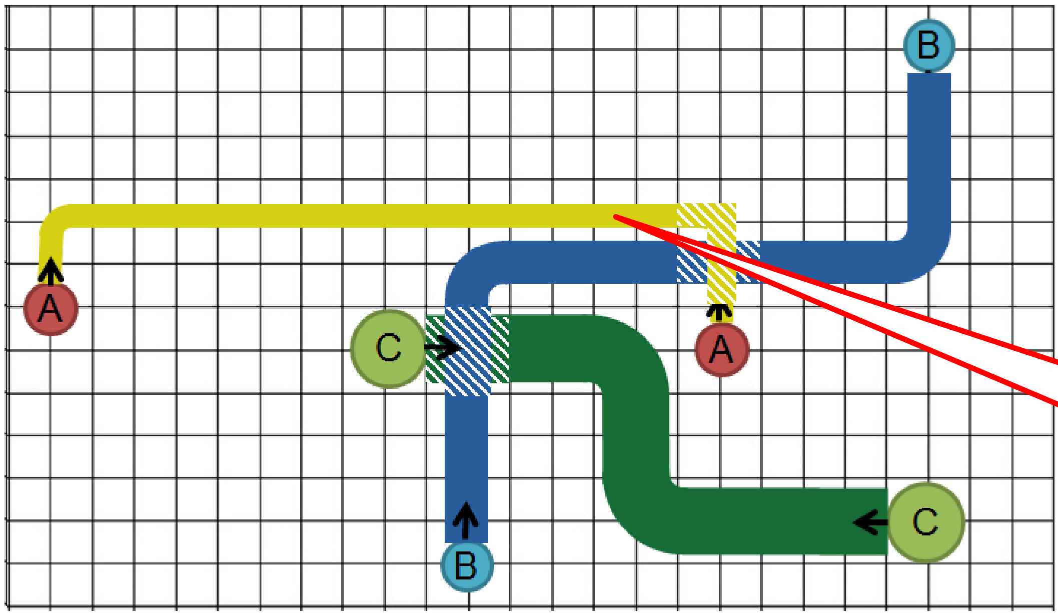

Re-arrange pipes with the order of the pipe's length.

Approach: Interference avoidance of multiple pipes

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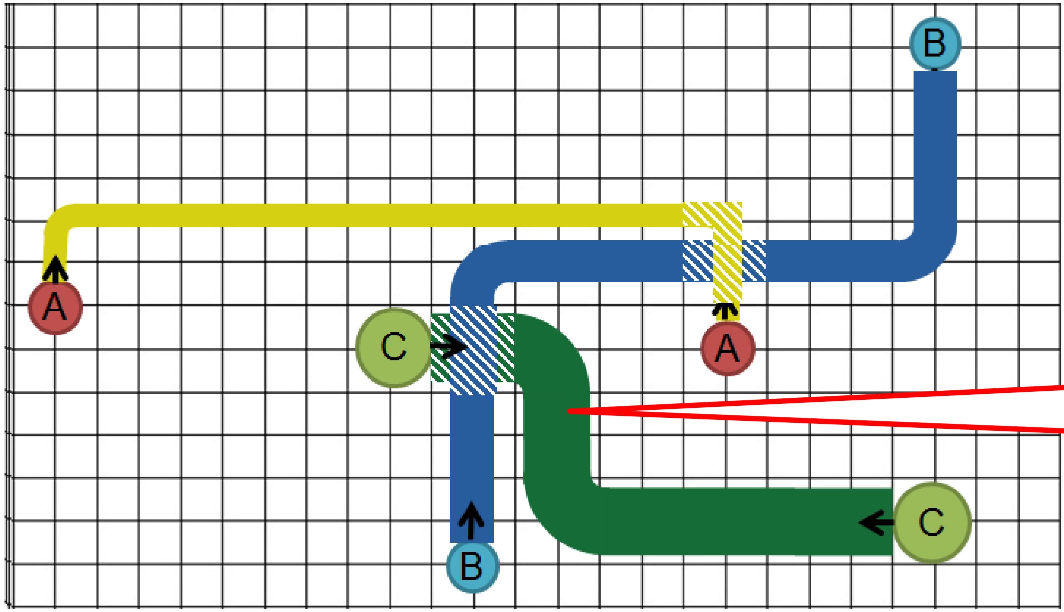

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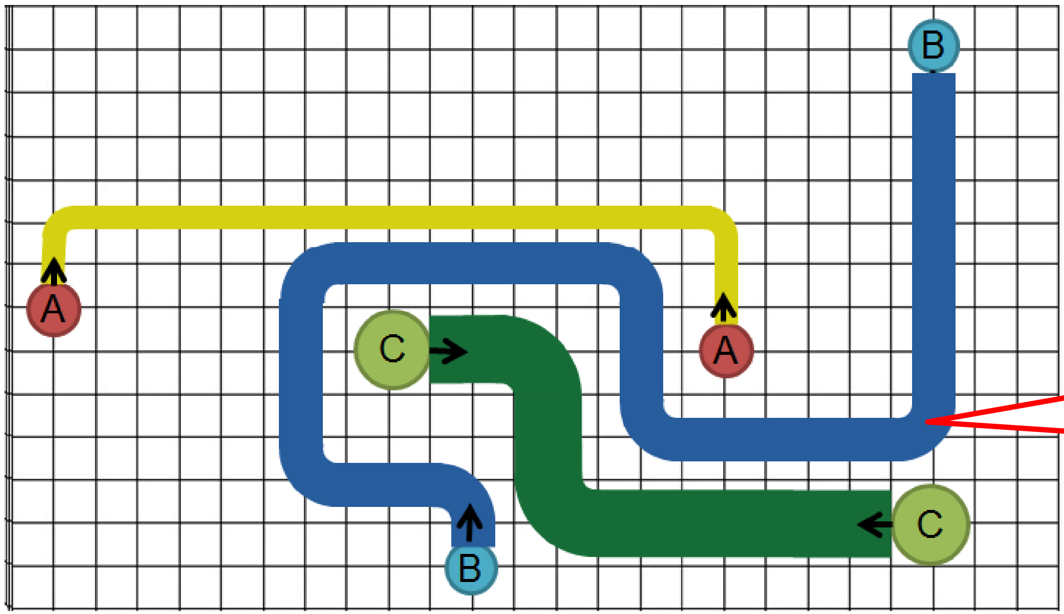

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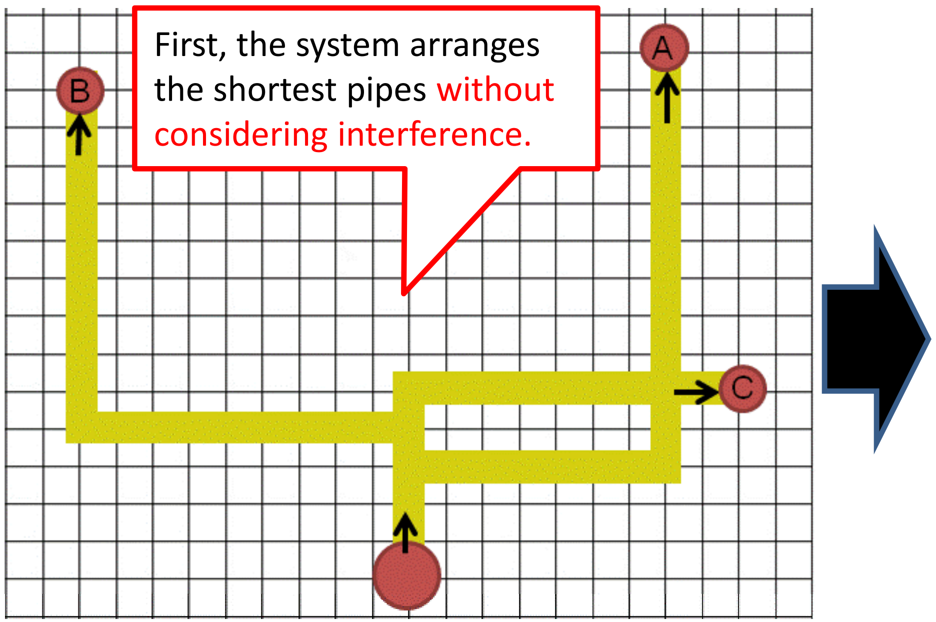
Touch and Cross Method for Branches



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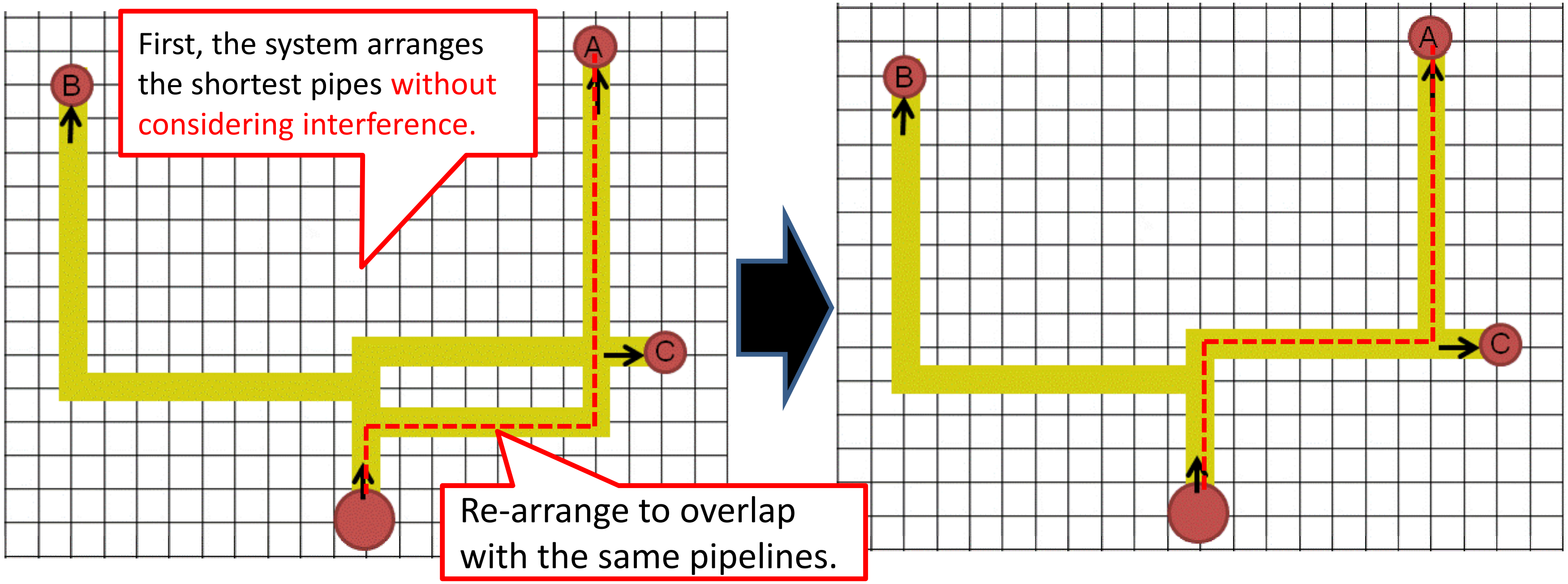

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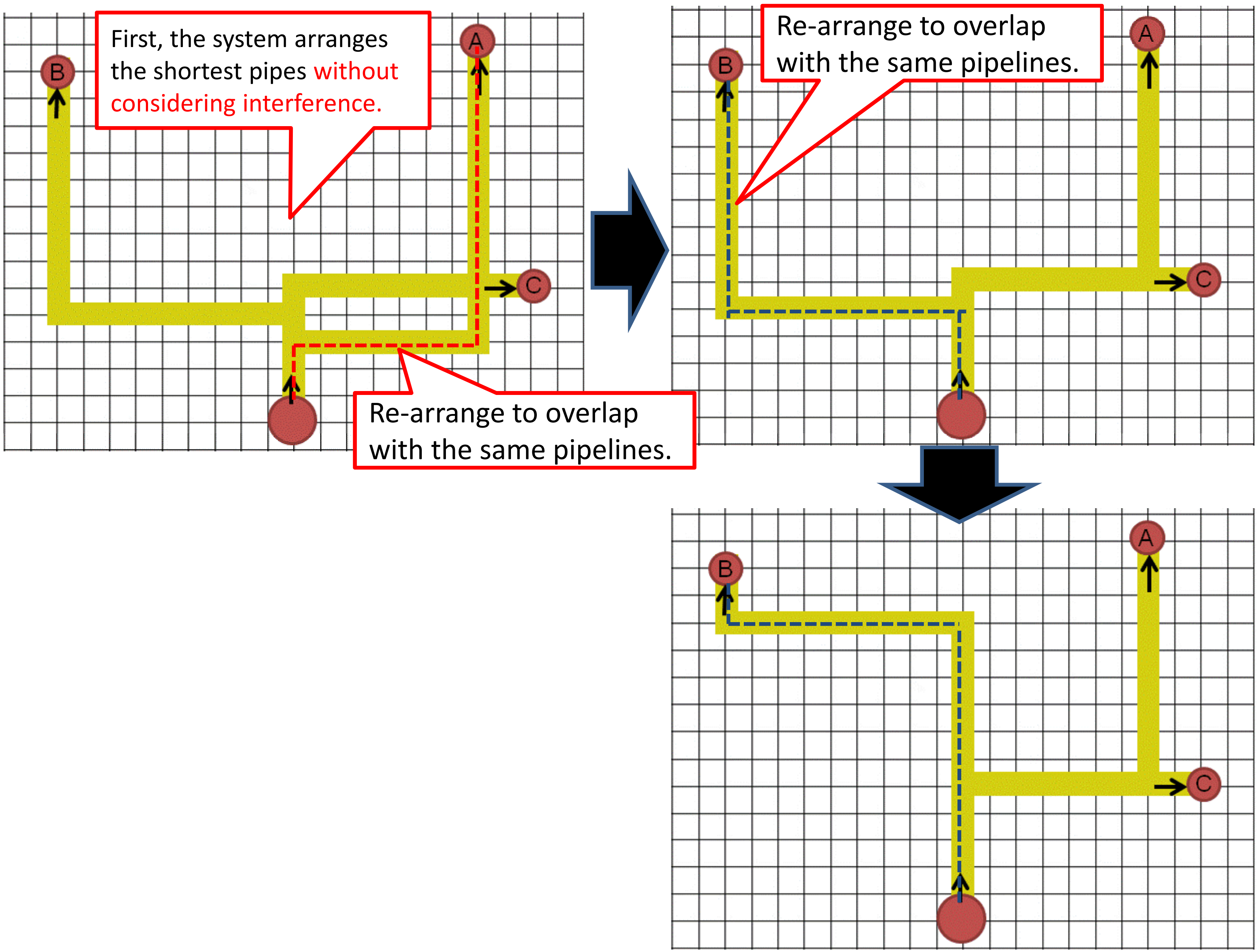

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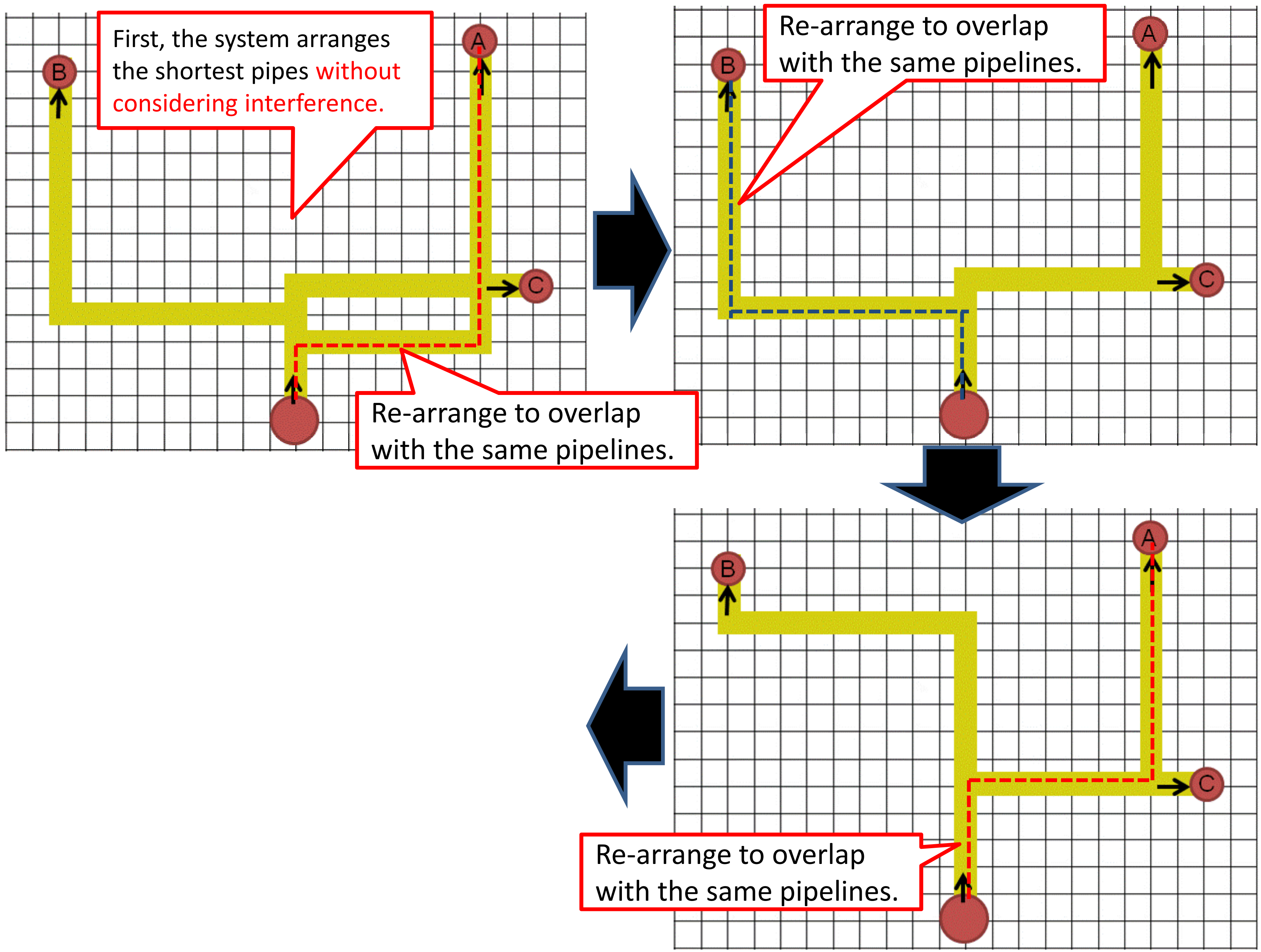

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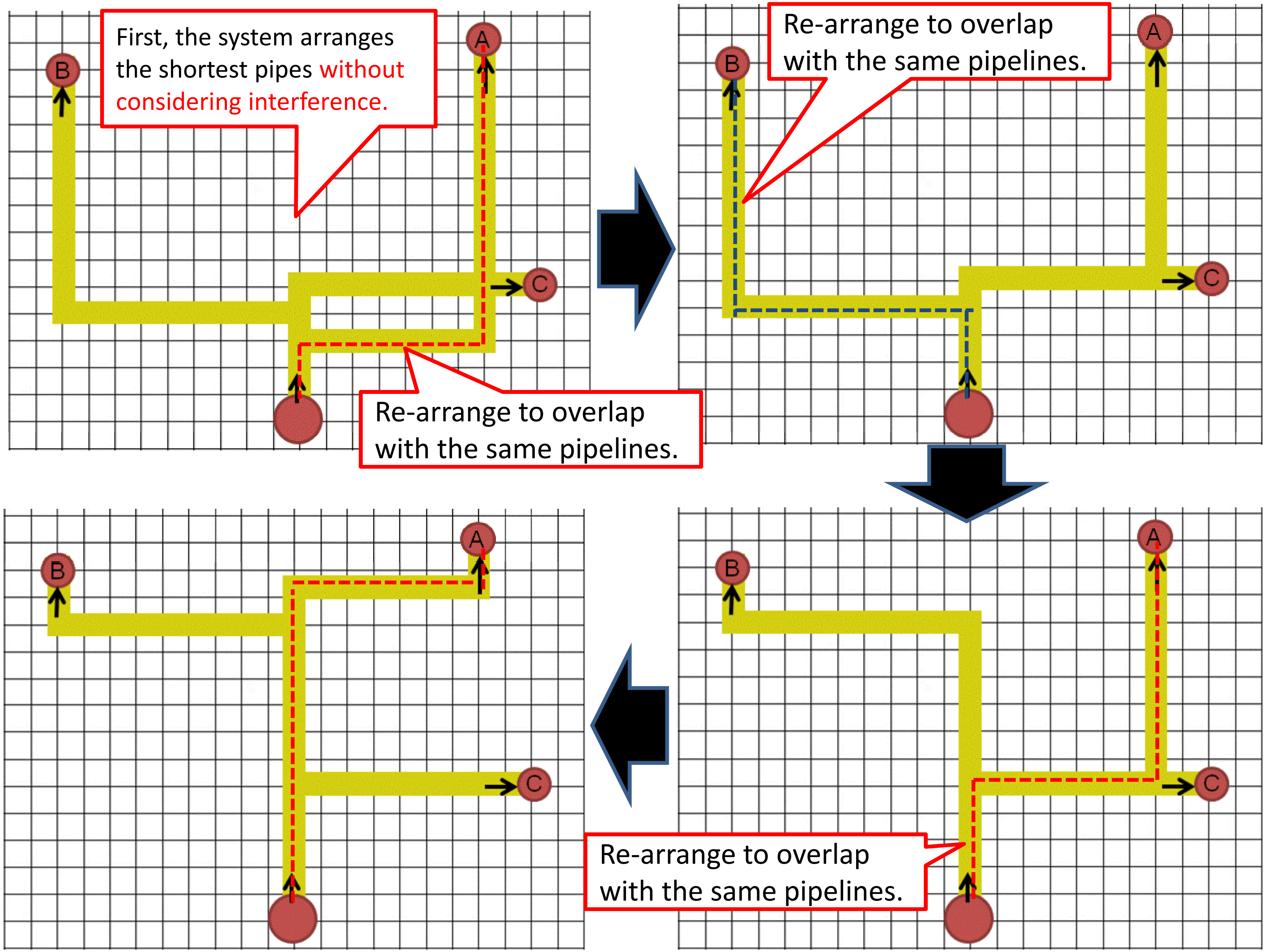
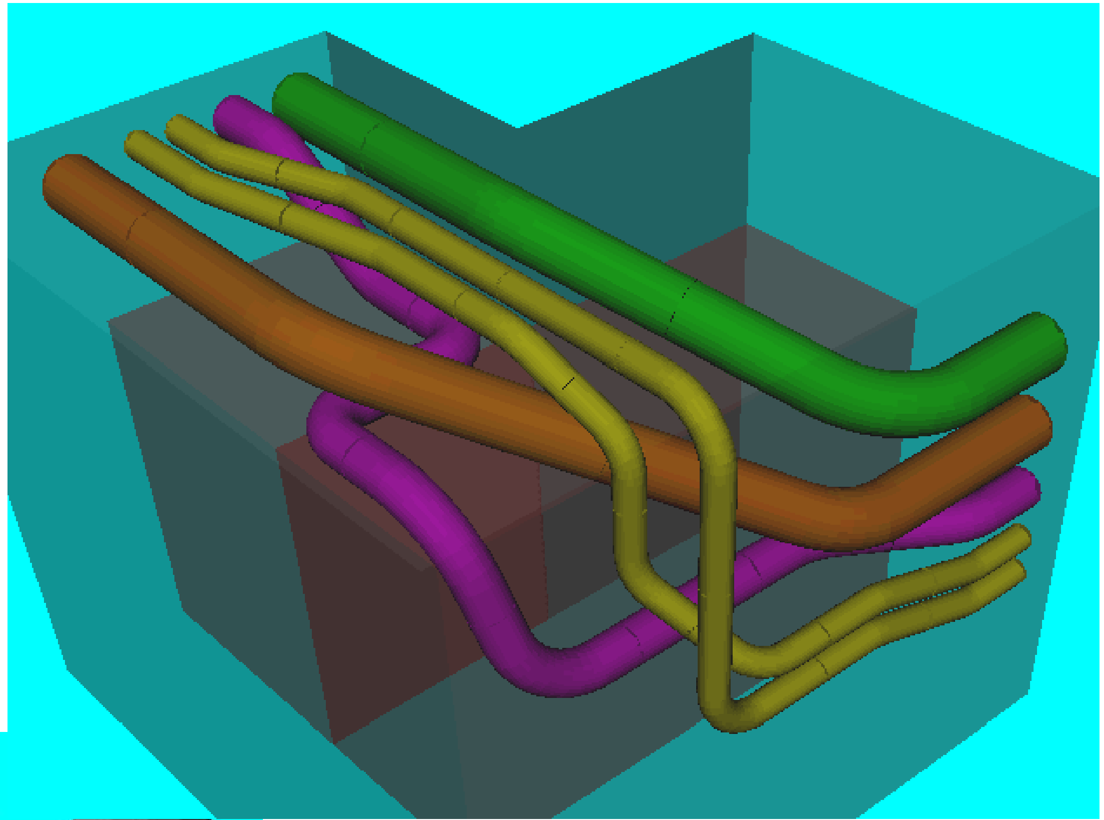
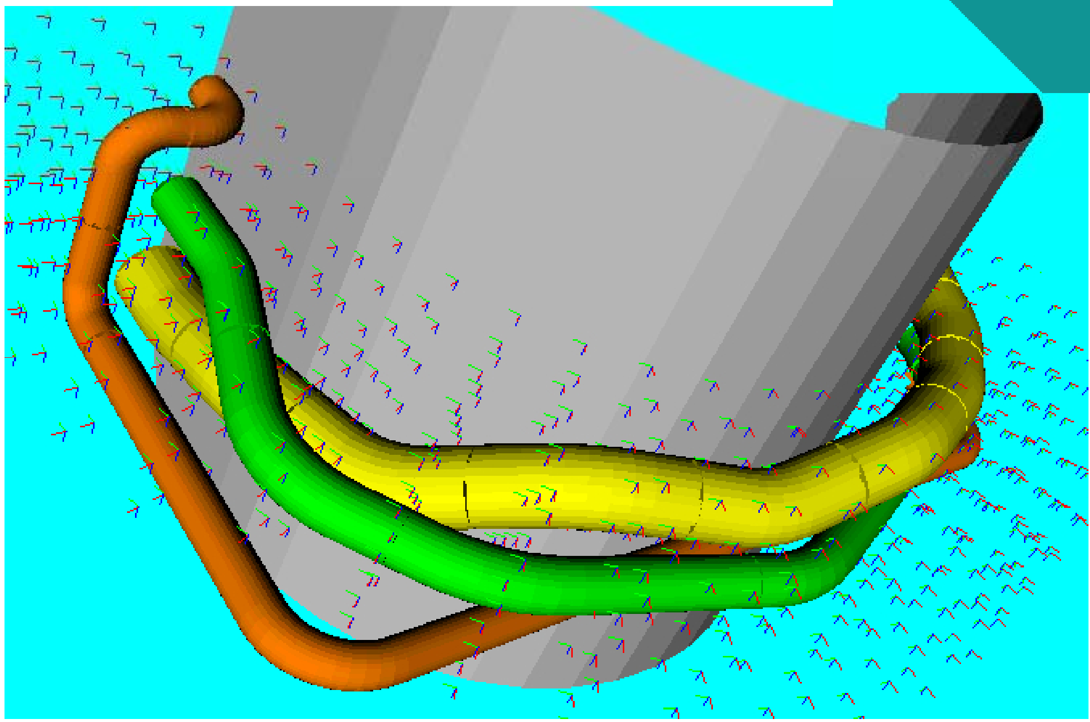


DEMO





Computer Simulations

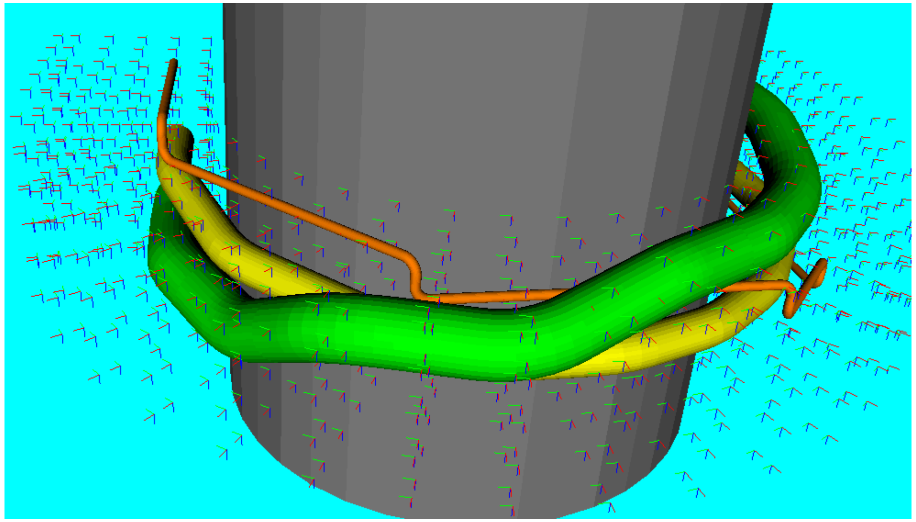
【Experiment 1】 Arrangement along curved structures

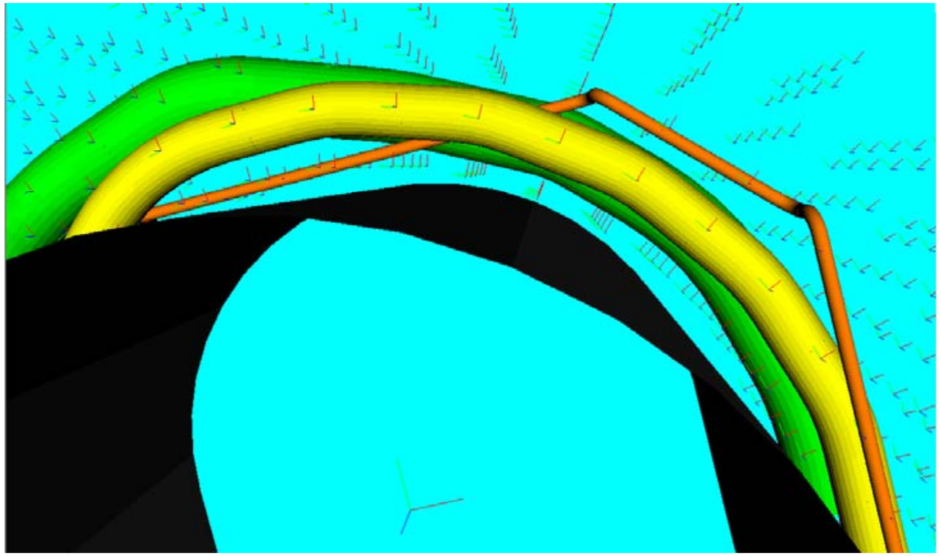
Φ600 bend's radius: 2400 or 1200
Φ400 bend's radius: 1600 or 1200
Φ100 bend's radius: 300 or 150
The minimum length of the straight pipe between elbows: Over 200 in ϕ600 and 400 pipes and 100 in ϕ100 pipe.

The angle of the bend is 90 deg only in Φ100
The others are arbitrary (maximum is 90 deg)

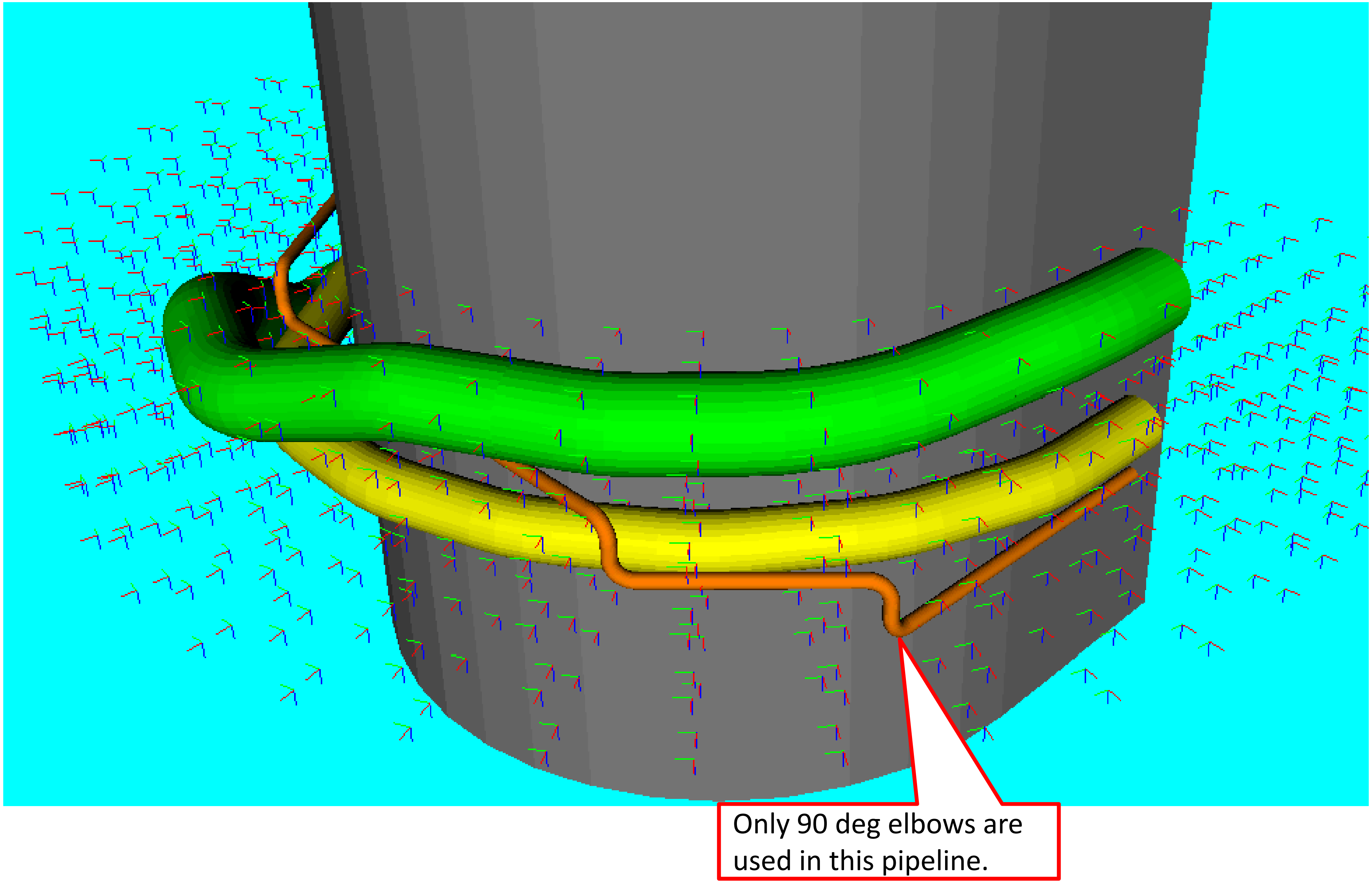
Size of structures: half of a cylinder, radius 3000
with a plane which is the length 200

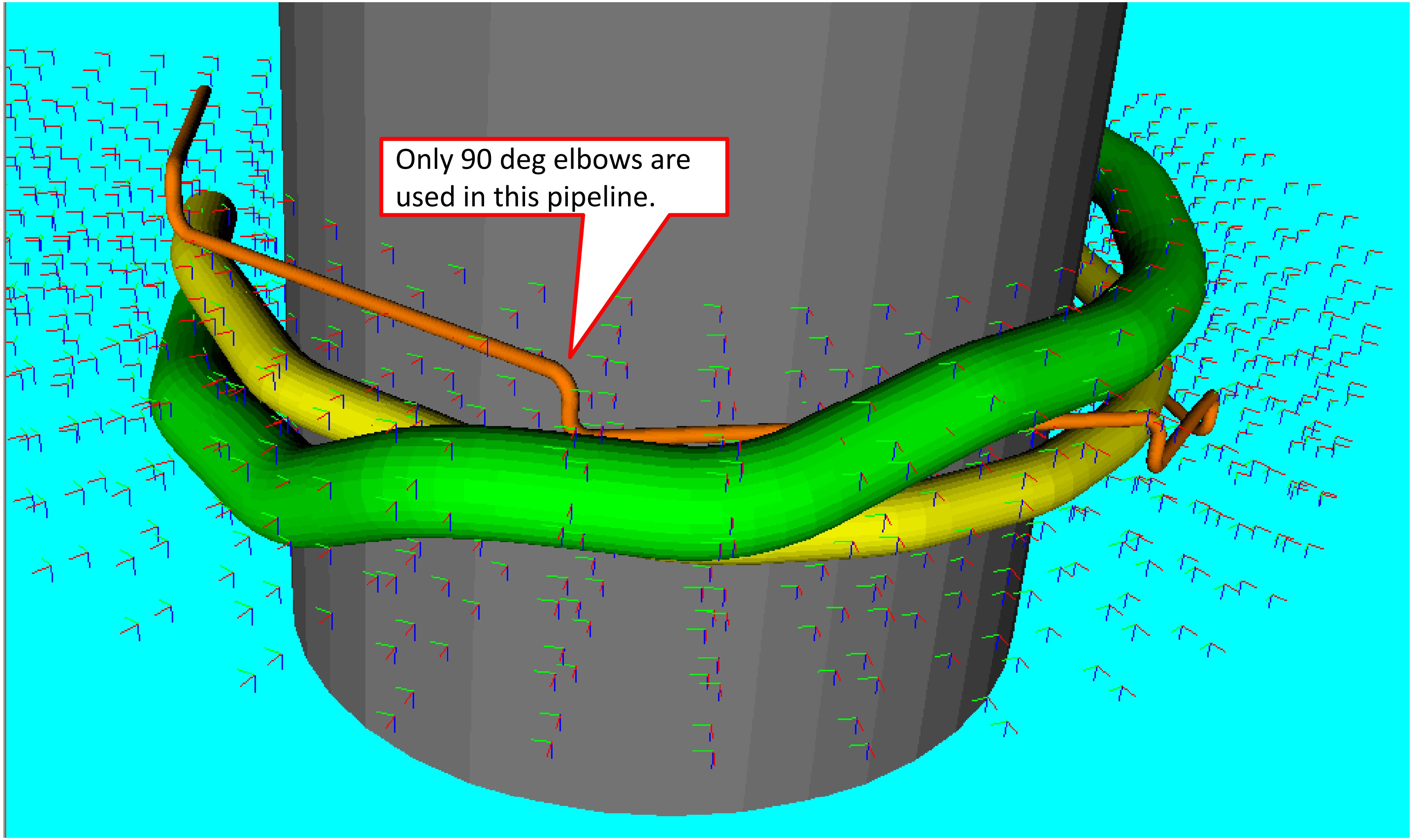
Arrangement of the design points:
interval 400 in the height direction,
In the direction of radius in the cylinder,
away 200 from the wall, interval 400,
in the direction to the circumference,
divide 180 deg. into 20, then 870 points





Almost the same solutions in all trials
It takes 2~3 minutes, sometimes failed.


Only 90 deg elbows are
used in this pipeline.


Only 90 deg elbows are used in this pipeline.

Computer Simulations

【Experiment 2】

Design Space: **L**1500 W4000 H2000

D × num: Φ200×2, Φ150×1, Φ100×2

Aisle: (shown in the red box)

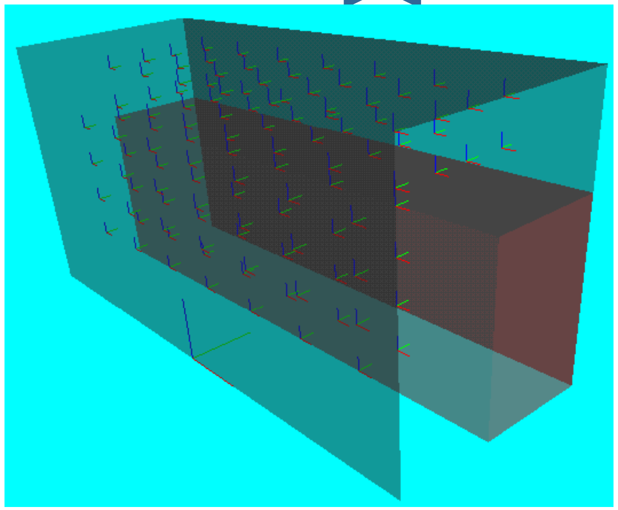
L800 H1300 W4000

Piping Supports:

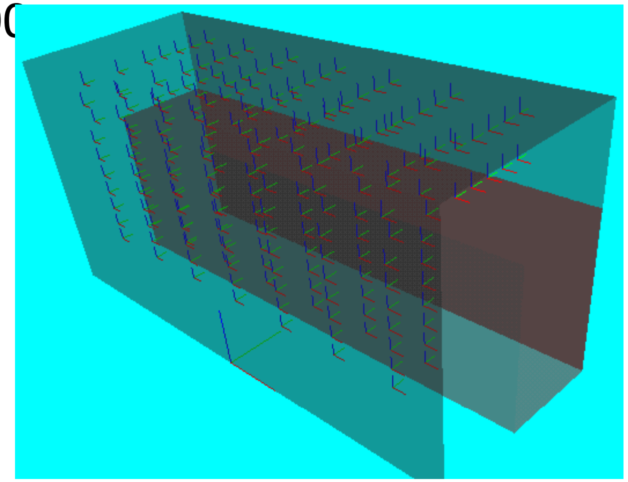
Horizontal supports away from the roof 100 and 400

Vertical supports away from the wall 100 and 400

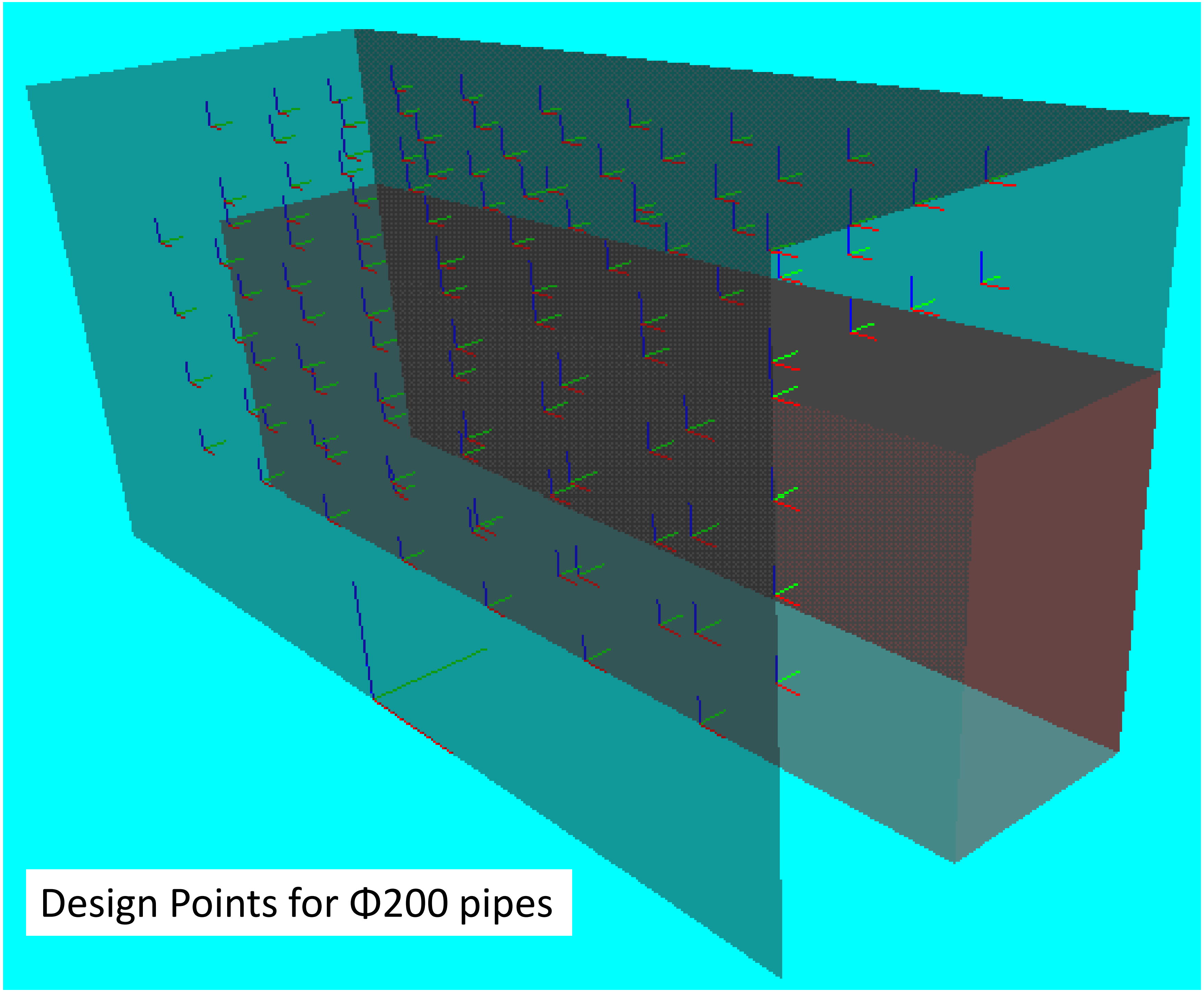
They are arranged in 500 intervals along W



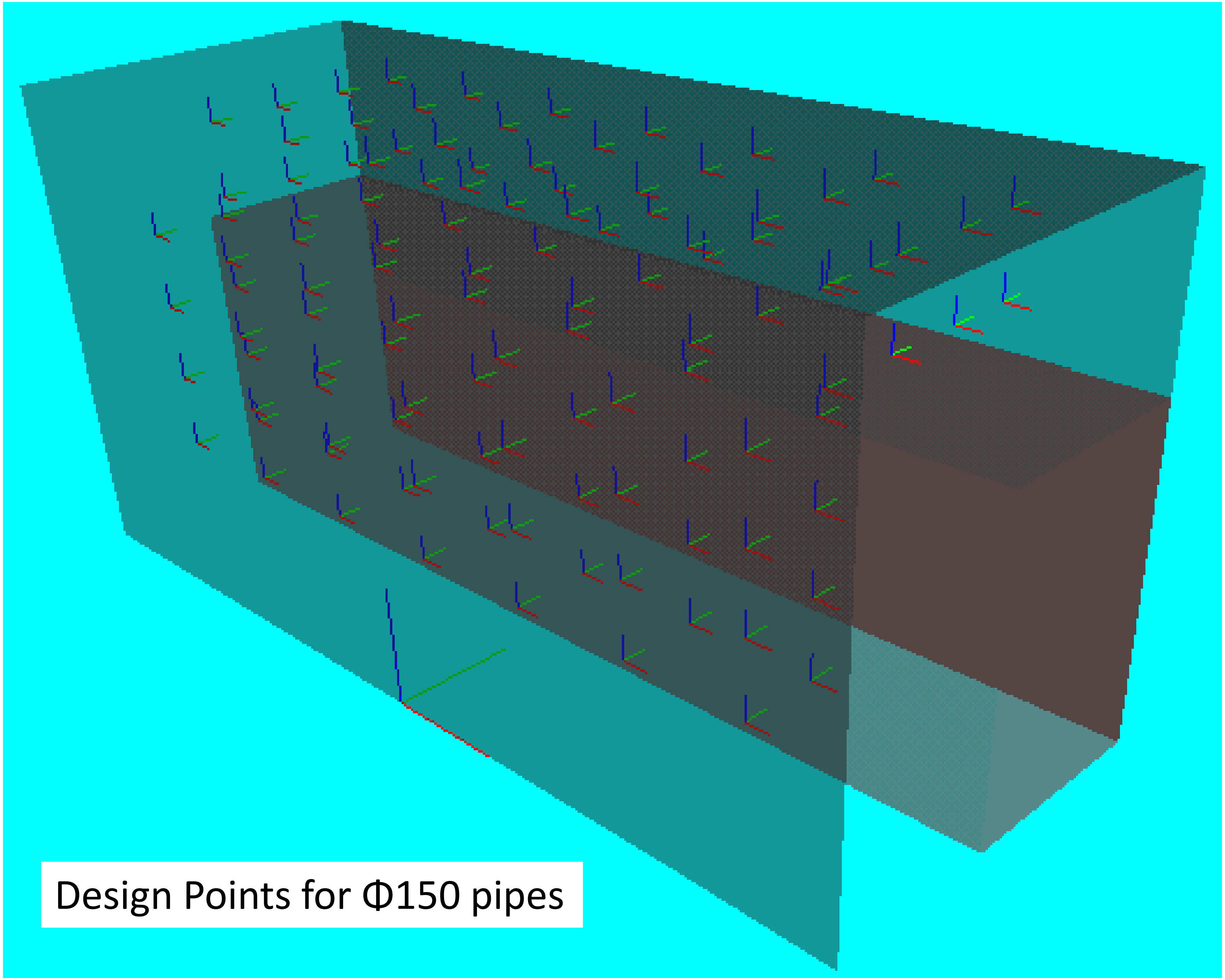
Φ200パイプ用の経由点候補



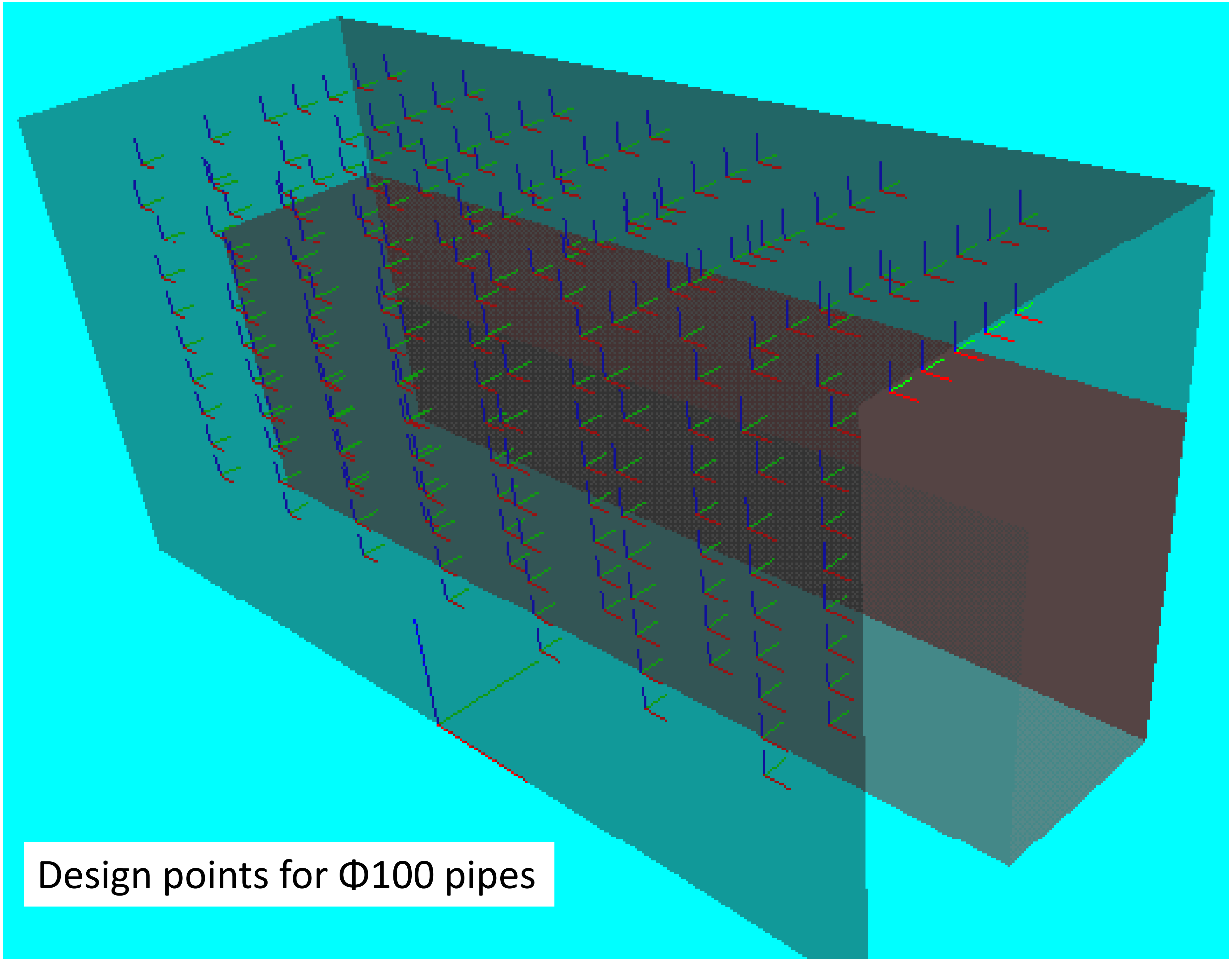
Φ100パイプ用の経由点候補



Design Points for Φ200 pipes



Design Points for Φ150 pipes



Design points for Φ100 pipes

Results of Experiment (2)-1

For Ship Design (**Arbitrary angle elbows**)

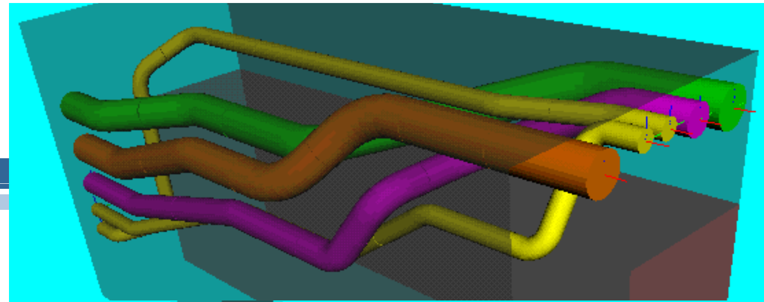
Φ200 bend's radius: 400 or 300
Φ150 bend's radius: 300 or 150
Φ100 bend's radius: 200 or 100

The minimum length of the straight pipe between elbows: Over 100 in all diameters of pipes.

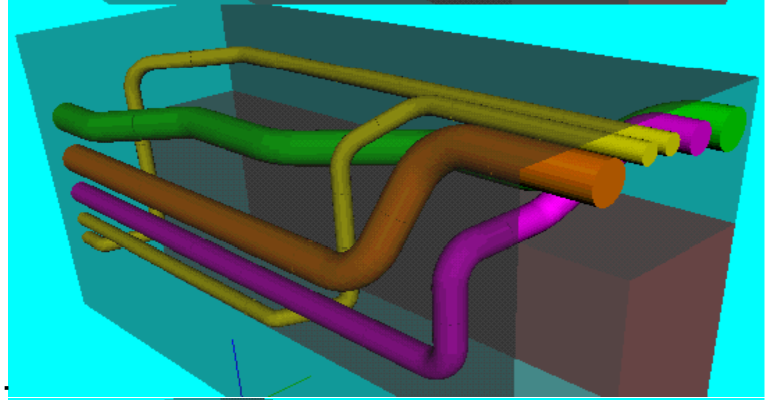
Maximum angle of the bend is 90 degrees

Cost of the pipe per unit length:
Φ200 : 40
Φ150 : 22.5
Φ100 : 10

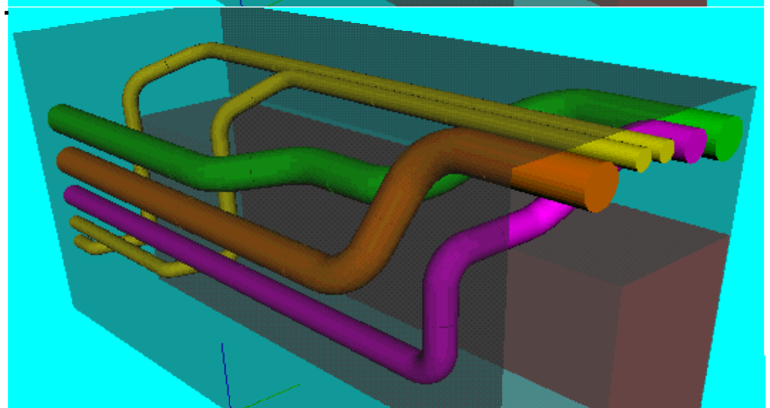
Cost of bends : 1000 constant that does not depend on the diameter nor angles



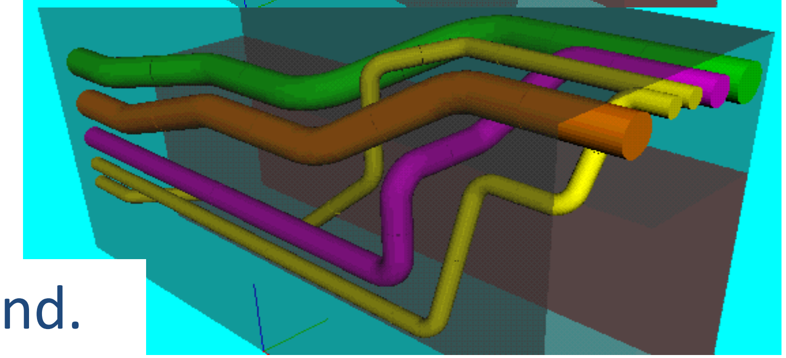
COST=1370167



COST=1171743



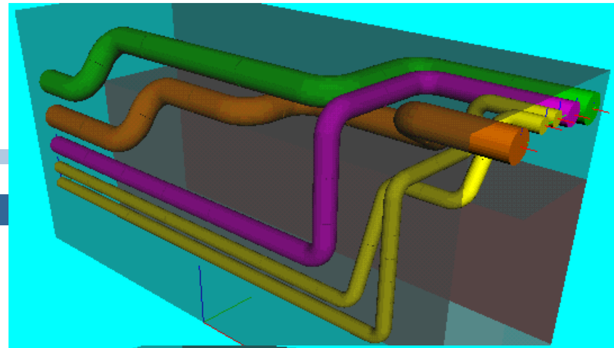
COST=1192755



COST=1318435

In all trials, different Solutions are found.

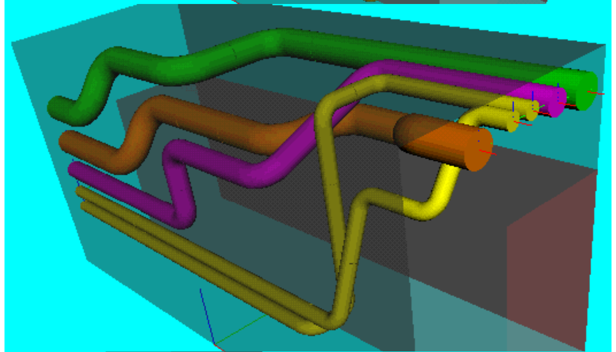
Results of Experiment (2)-2



COST=1368599

For Building Design（**90 degree elbows**）

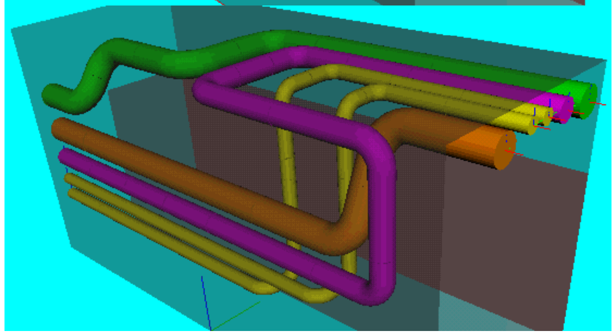
Φ200 bend's radius： 400 or 300
Φ150 bend's radius: 300 or 150
Φ100 bend's radius： 200 or 100



COST=1320220

The minimum length of the straight pipe between elbows：
Over 100 in all diameters of pipes.

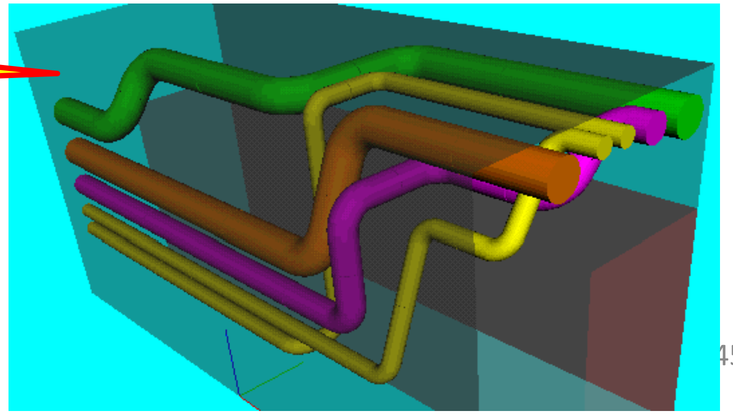
The angle of the bends is only 90 degree.



COST=1281864

Cost of the pipe per unit length:
Φ200：40
Φ150：22.5
Φ100：10

No detour

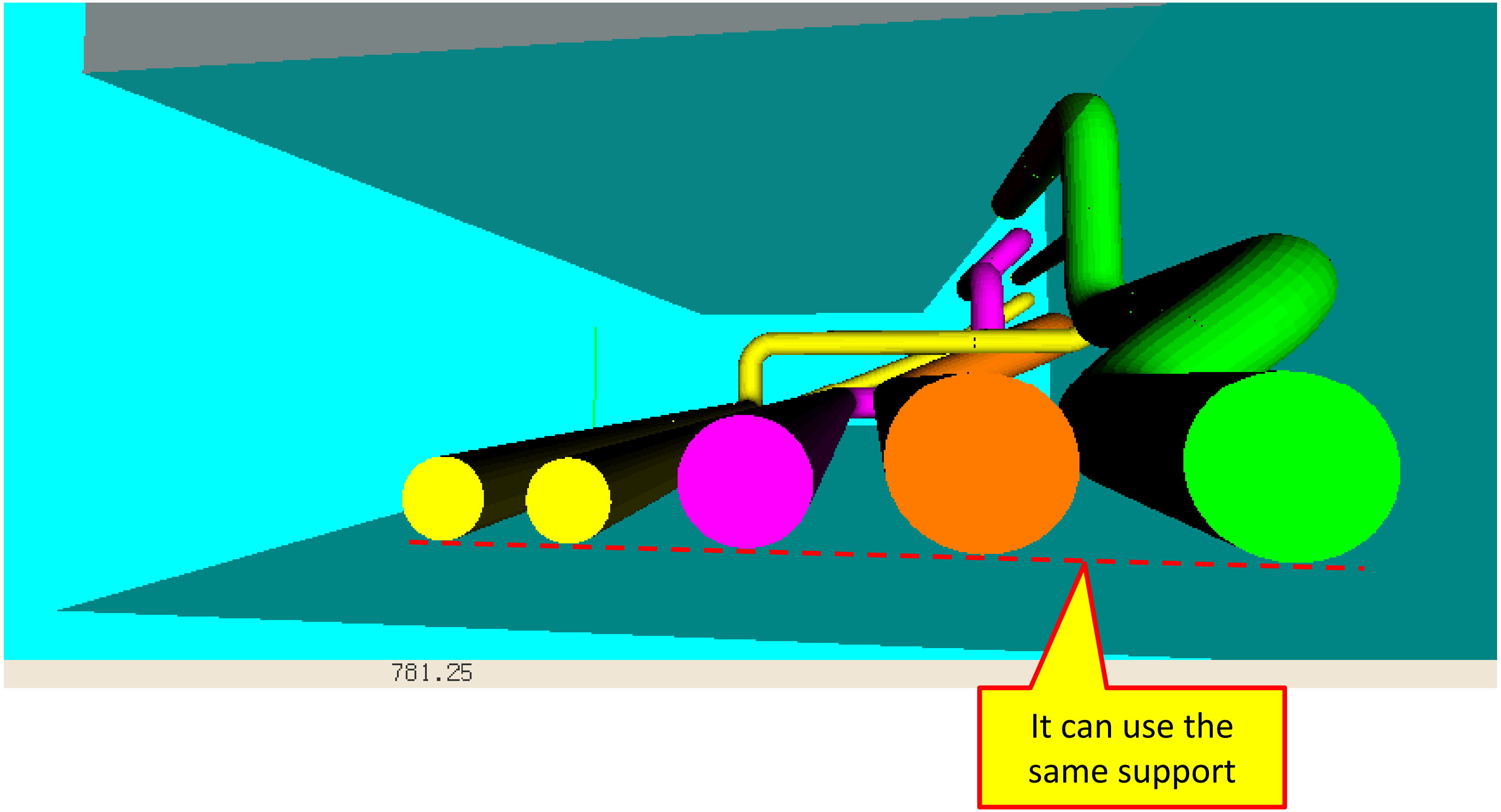


COST=1181384

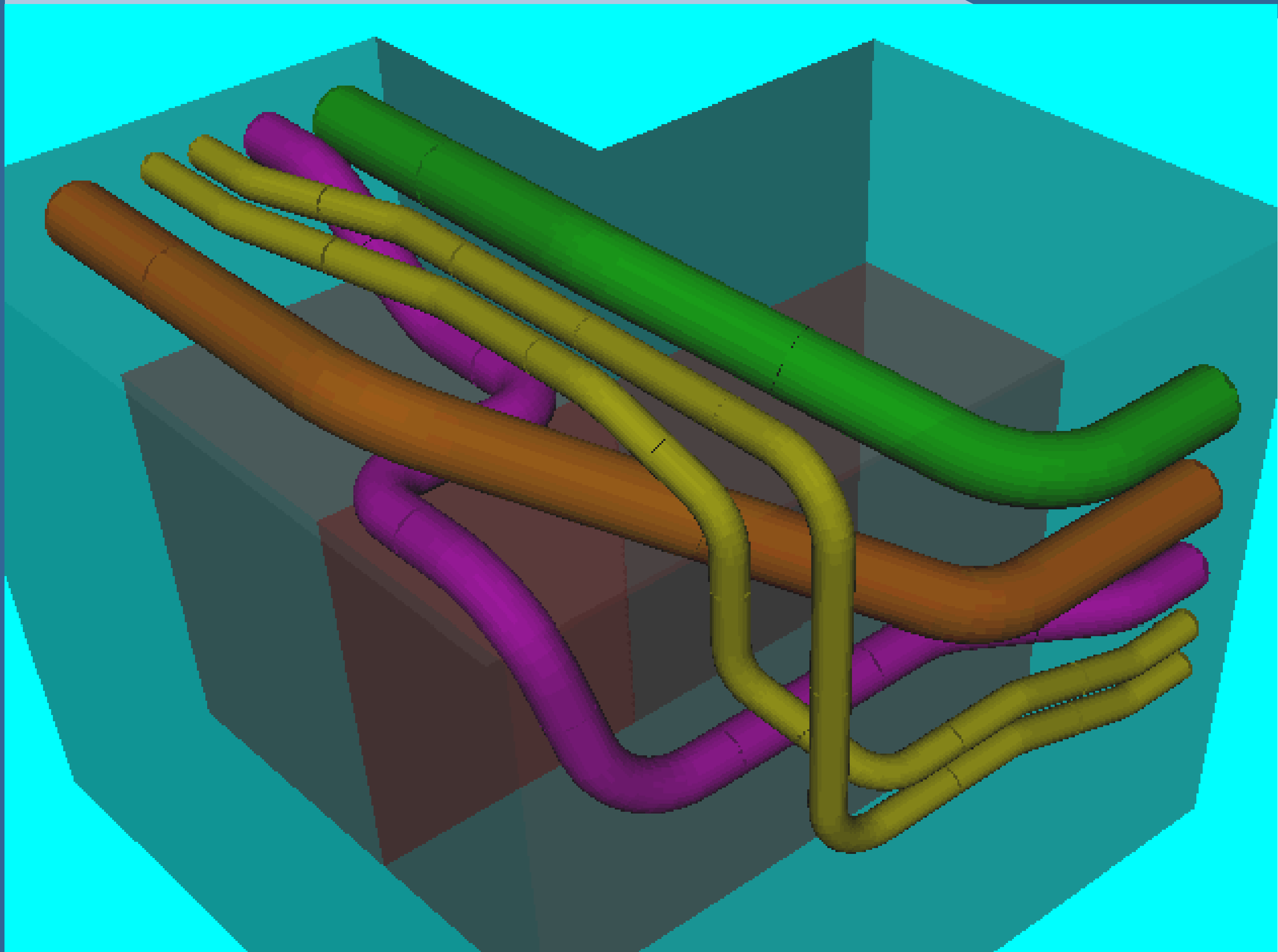
Cost of bends : 1000 constant
that does not depend on the diameter nor angles

In all trials, different Solutions are found.

In 10 trials, failed 4 times（truncated 4 min.）


781.25
It can use the same support

Result of Experiment 2 ‘



It cannot find any solution with using only 90 degree elbows.

Discussion

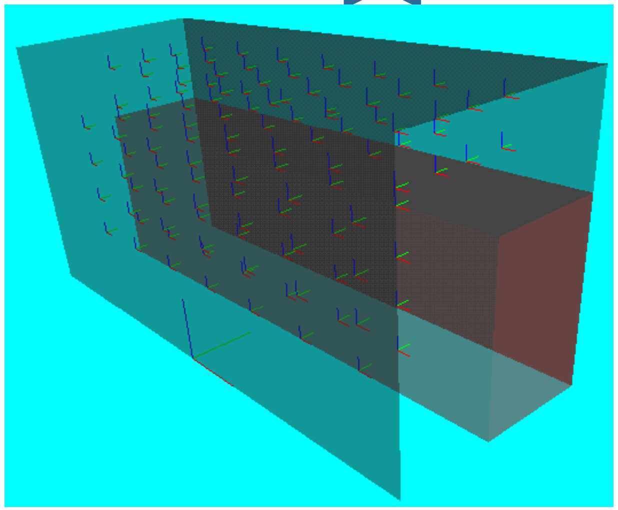
◆The number of design points

In experiment 2, the system can find feasible solutions,

However, when the number of design points are decrease, It could not find any solutions.

→ **Appropriate arrangement of design points** is very important!

Future work



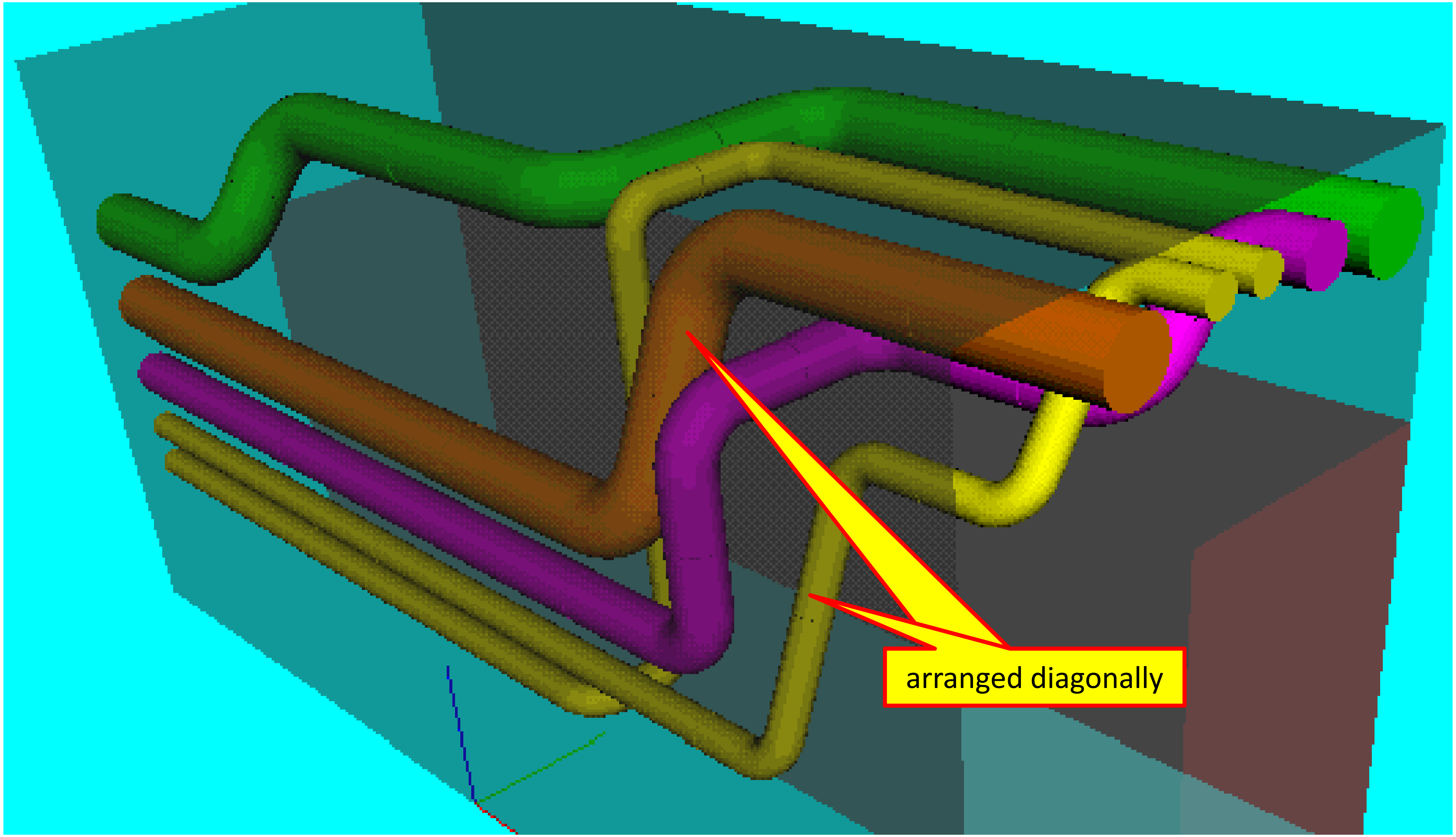
◆Different solutions in trials

Solutions are largely depend on the initial path

→ Improve touch and cross method so as to find best solutions certainly

◆The Solution in the constraint of 90 degree elbows:

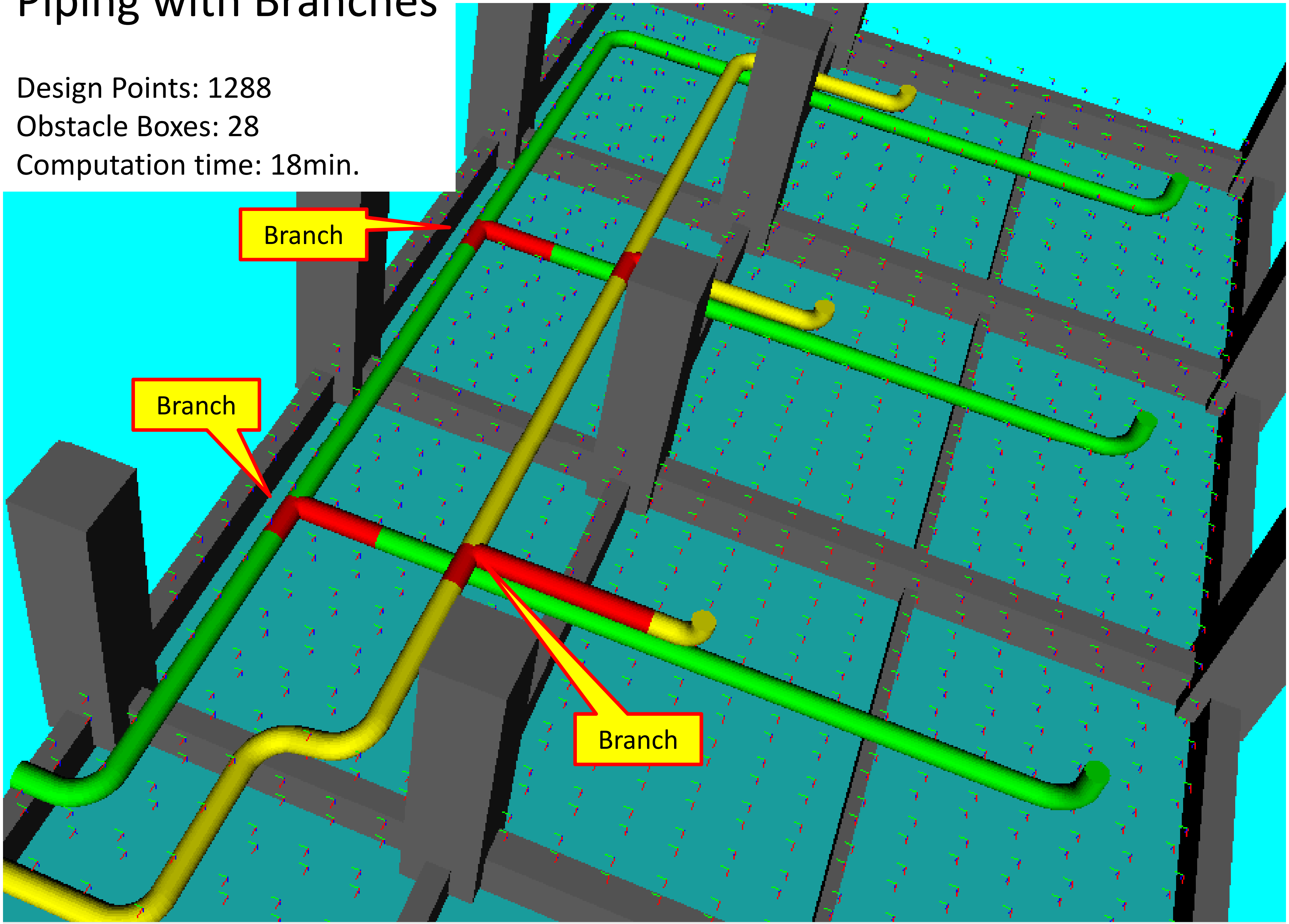
Although the elbows are 90 deg, some pipes are arranged diagonally → Real piping design



◆A solution in the constraint of 90 degree elbows

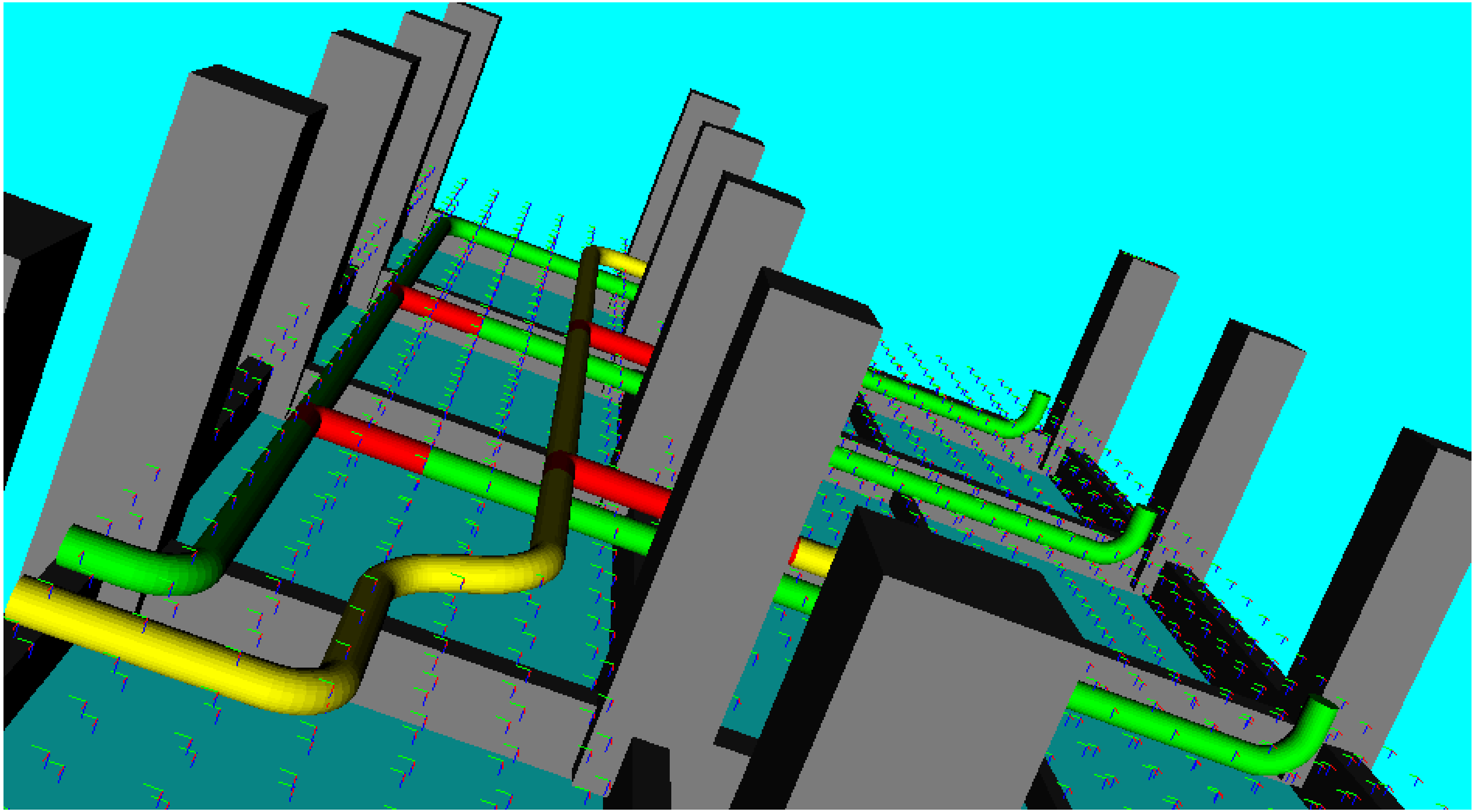
Piping with Branches

Design Points: 1288
Obstacle Boxes: 28
Computation time: 18min.



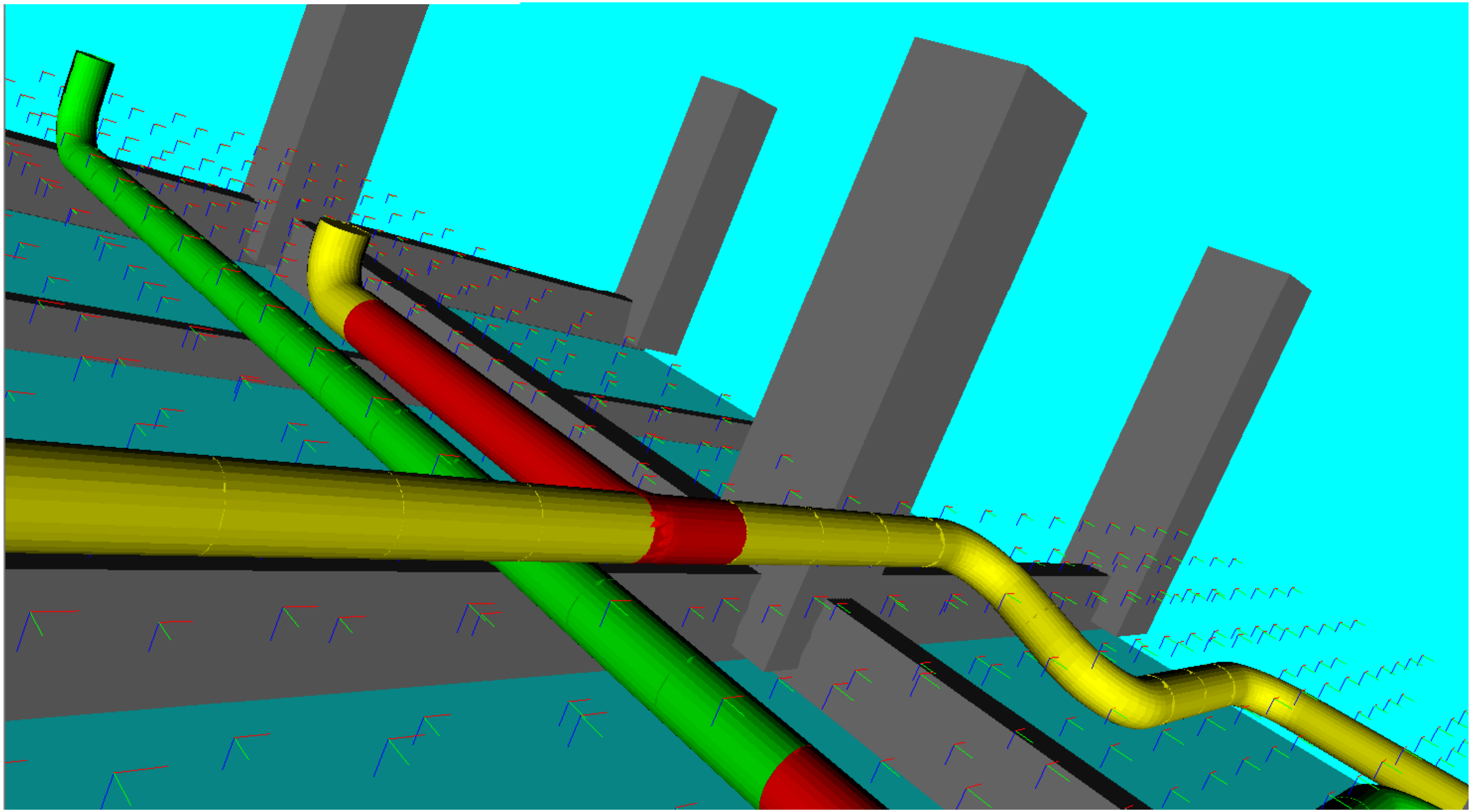
Piping with Branches

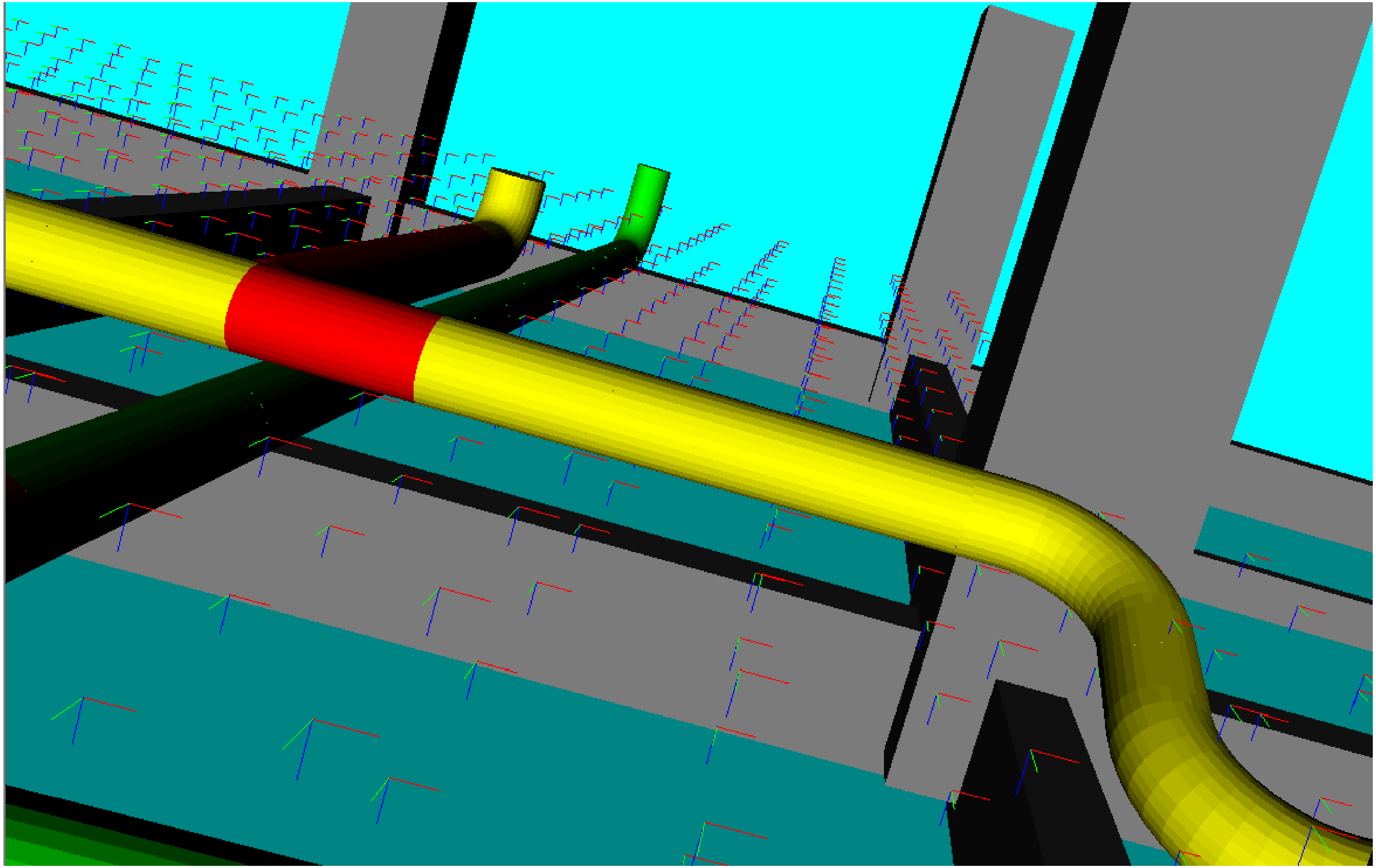
Design Points: 1288
Obstacle Boxes: 28
Computation time: 18min.



Piping with Branches

Design Points: 1288
Obstacle Boxes: 28
Computation time: 18min.



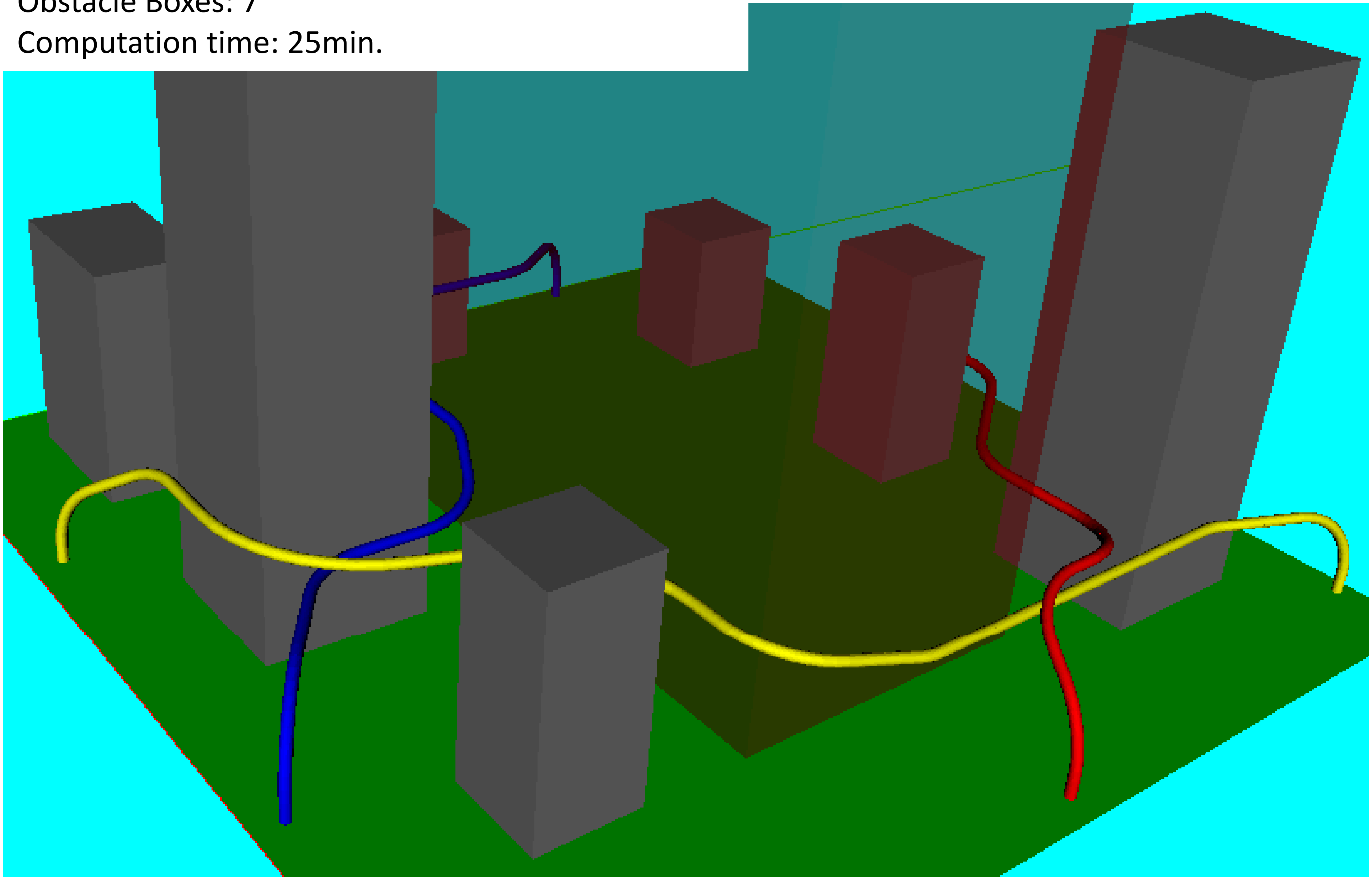


Path Planning of Multiple Drones

Design Points: 2000

Obstacle Boxes: 7

Computation time: 25min.

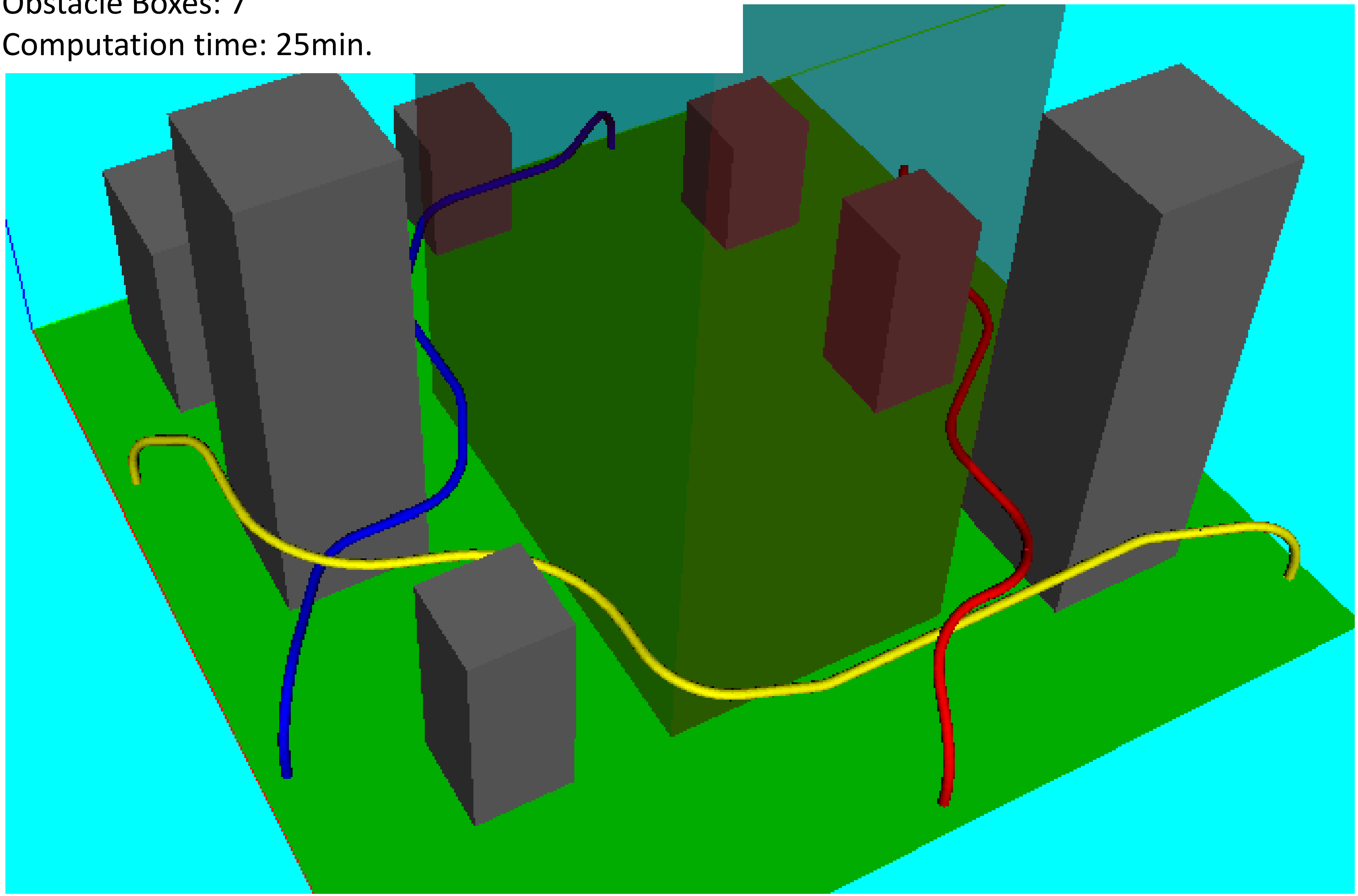


Path Planning of Multiple Drones

Design Points: 2000

Obstacle Boxes: 7

Computation time: 25min.

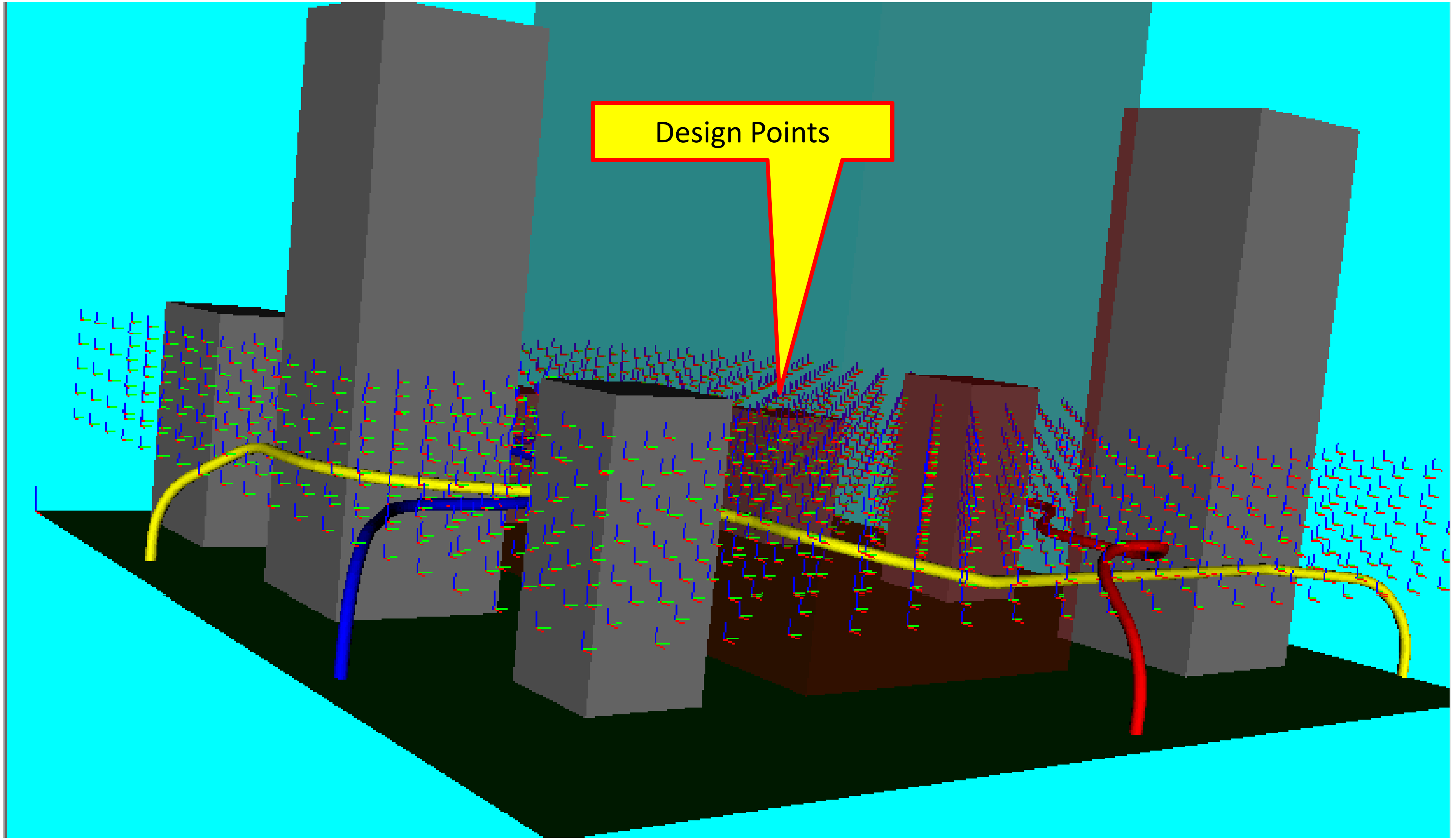


Path Planning of Multiple Drones

Design Points: 2000

Obstacle Boxes: 7

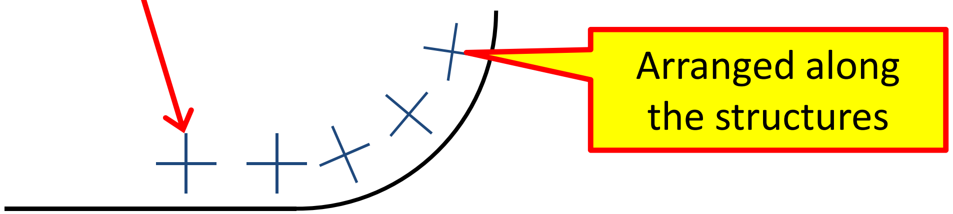
Computation time: 25min.

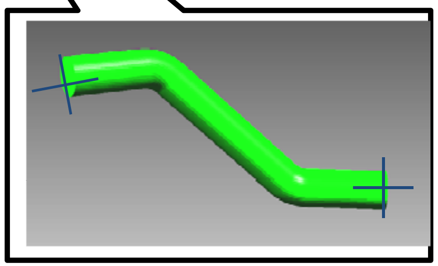


Conclusion

◆ On the routing problem for one pipe, to deal with supports and arrangement along curved structure, a new approach is proposed:

Design points that indicates direction and position are arranged in advance as candidates of waypoints of the pipe, and generate weighted graph checking whether two design points can connect by a pipe which satisfies the constraint of the pipe bender. After that, generate piping path from the shortest path search in the weighted graph.





◆ **For multiple piping,** **Touch and cross method** is also applied to **avoid different pipelines**, and to **overlap the same pipelines**.

Remarks

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This technology is Patent pending by Kyushu University.
(Japanese Patent Application No. 2017-96845)

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