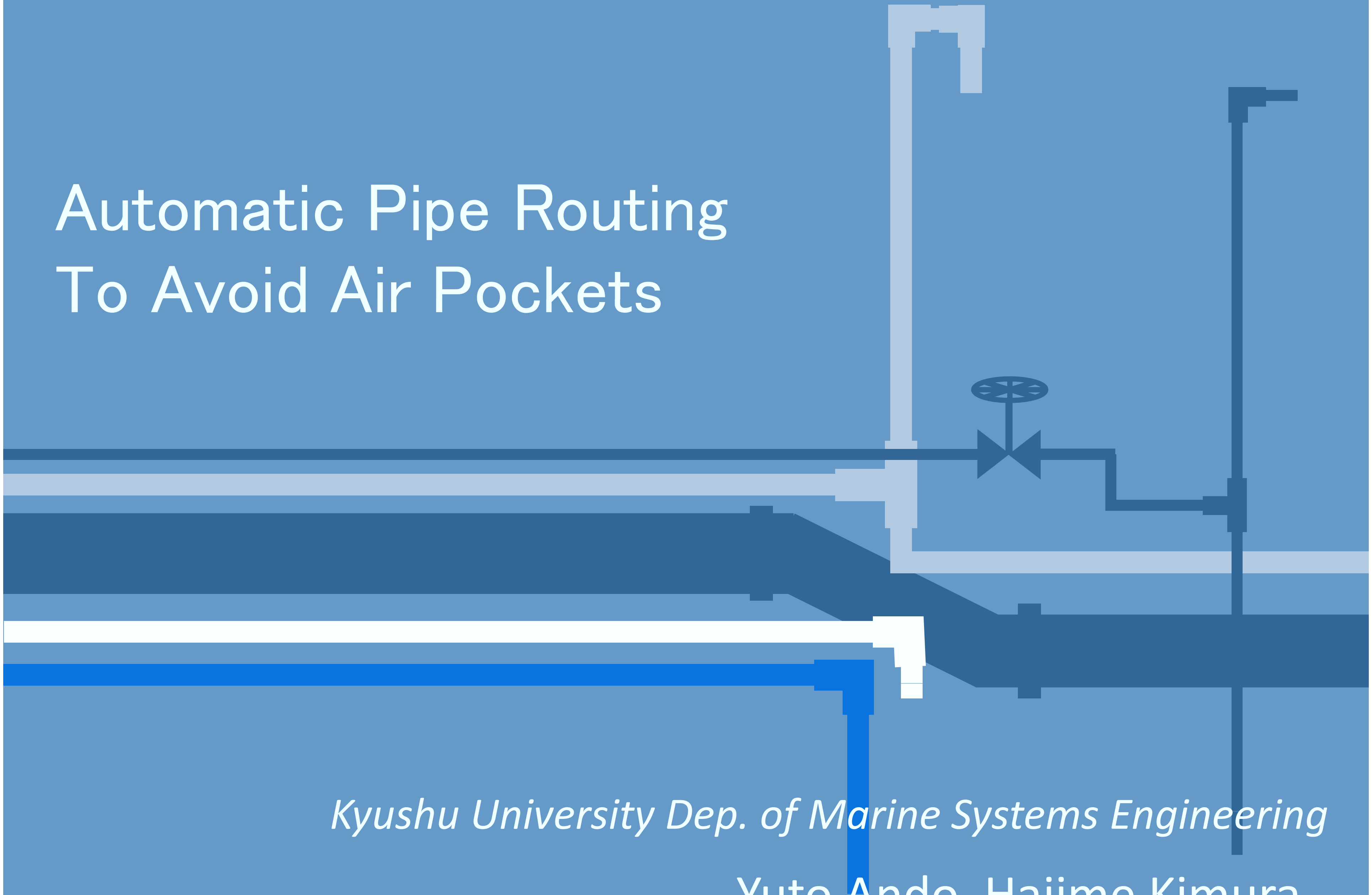
ICCAS2013 in Busan

Automatic Pipe Routing To Avoid Air Pockets



Kyushu University Dep. of Marine Systems Engineering

Yuto Ando, Hajime Kimura

Outline

- **Introduction**

1. Approach

2. Air Pockets

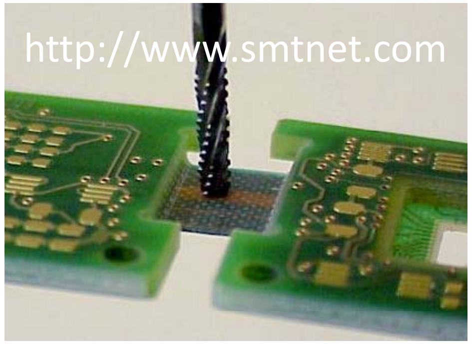
3. Simulations

- **Conclusion**

Motivations

Oil or Chemical Plants

Microchips



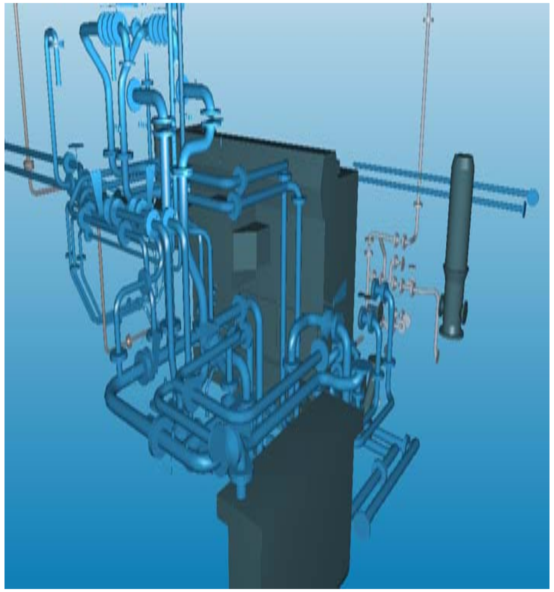
Ship Building

<u>Design of Pipelines</u>

Motivations

Design of Pipe-Line in Ship

- Positions of equipment (valves, etc.)
- Piping routes
- Estimation of safety



New Approach

Experience of Veterans

- A lot of time to design.
- Veterans are decreasing.

Design Complete!

Motivations

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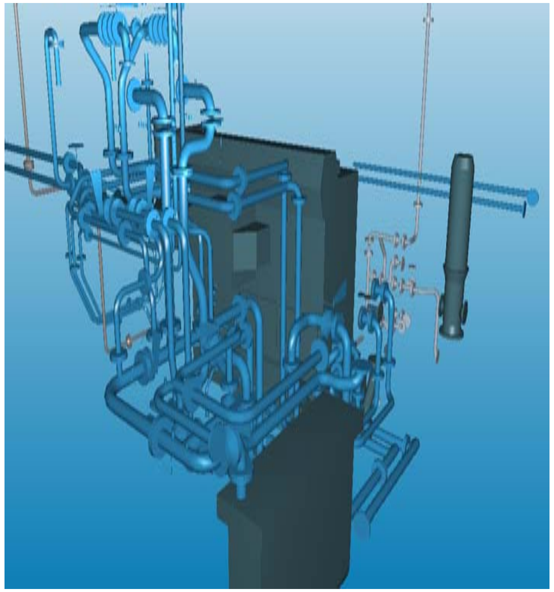

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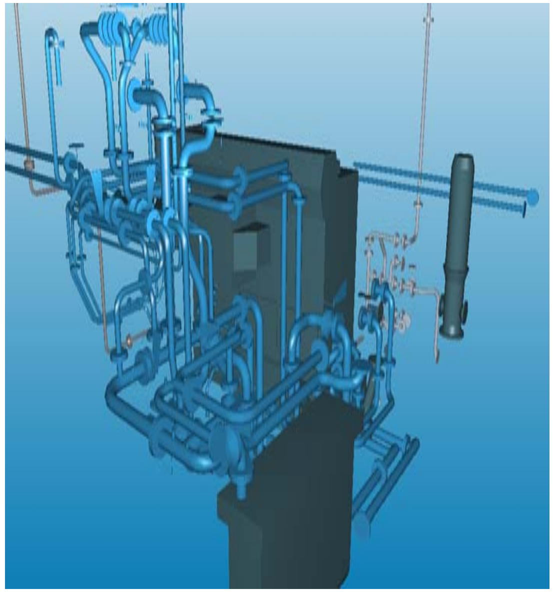


New Approach

Experience of Veterans

◆ A lot of time to design.

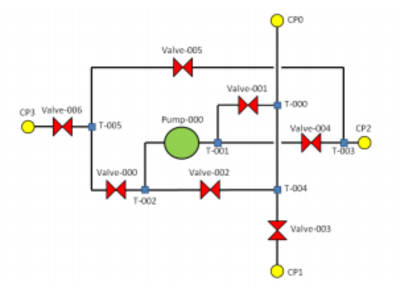
◆ Veterans are decreasing.

<u>Design Complete!</u>

Purpose

◆ Automatic Pipe-Line Design System

PID ➡ Automatic Design System ➡ **Final Design**

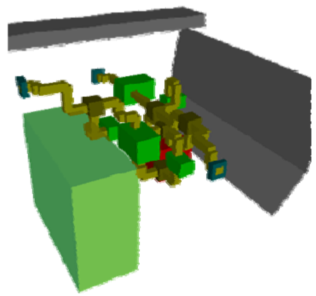


Equipment Placing System

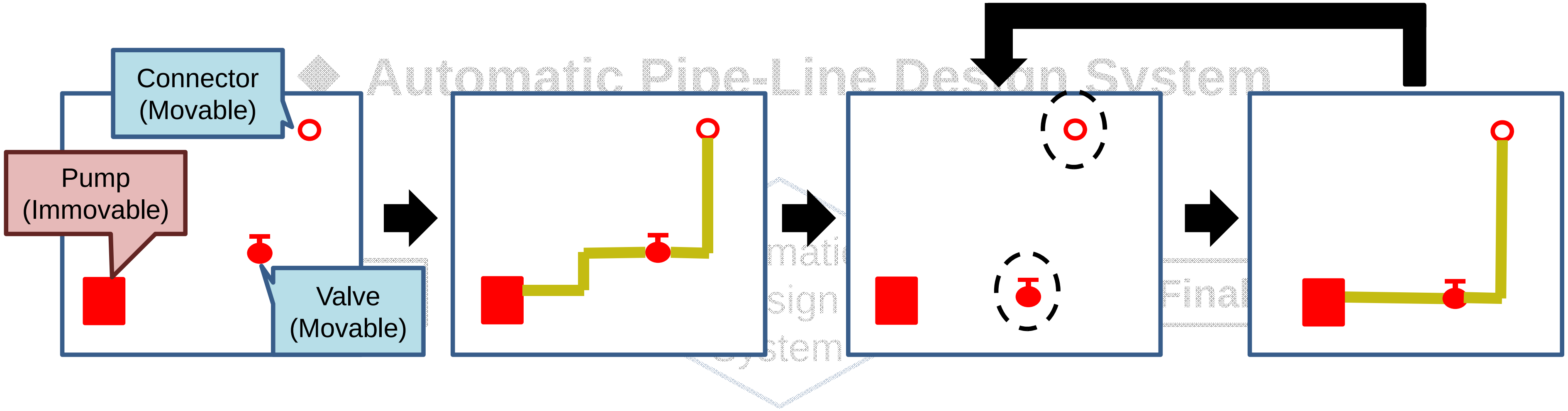
Equipment Layout

<u>Routing System</u>

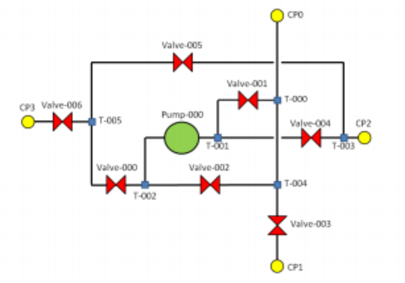
Pipe-Routes

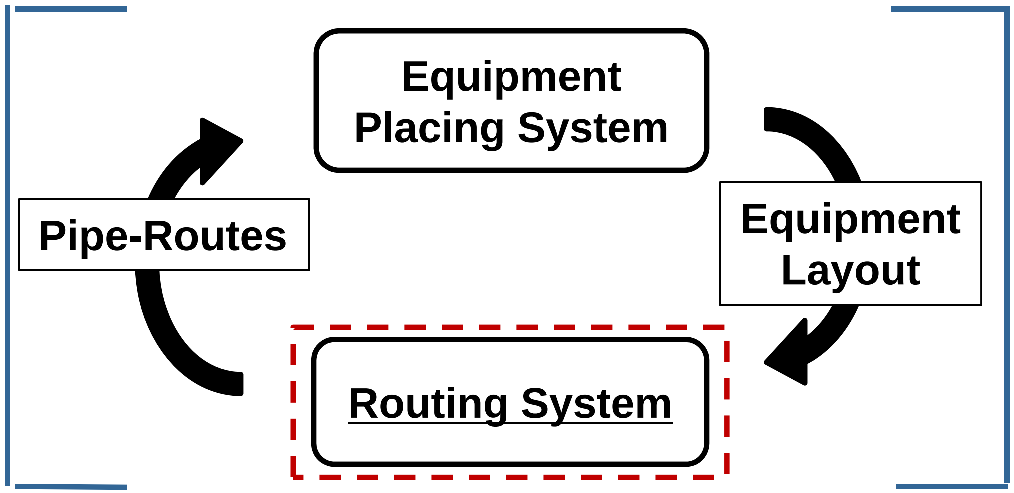


Purpose

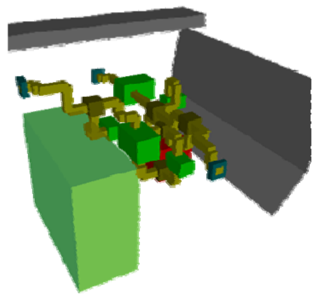


Connector
(Movable)
Pump
(Immovable)
Valve
(Movable)





Equipment
Placing System
Equipment
Layout
Routing System
Pipe-Routes



Outline

◆ Introduction

1. **Approach**

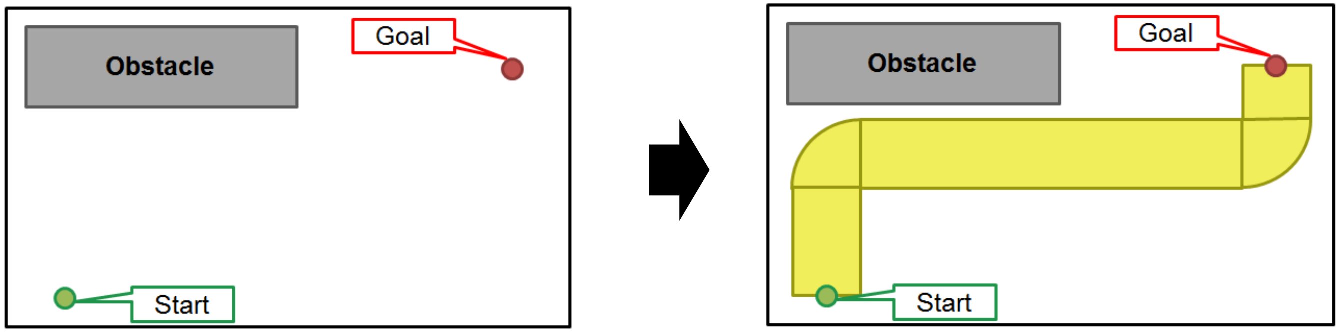
2. Air Pockets

3. Simulations

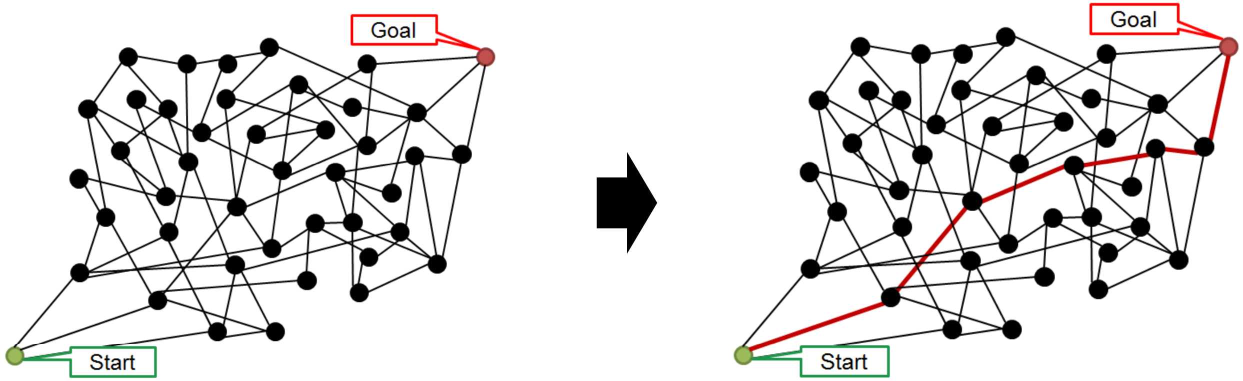
◆ Conclusion

Approach of Routing System

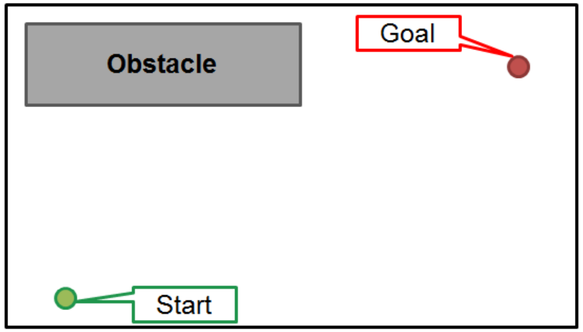
Routing of pipelines

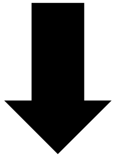


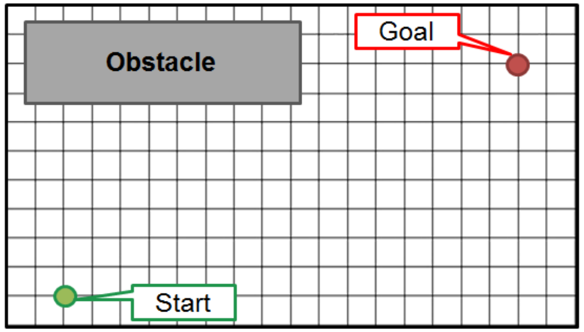
Routing in a network



Approach of Routing System







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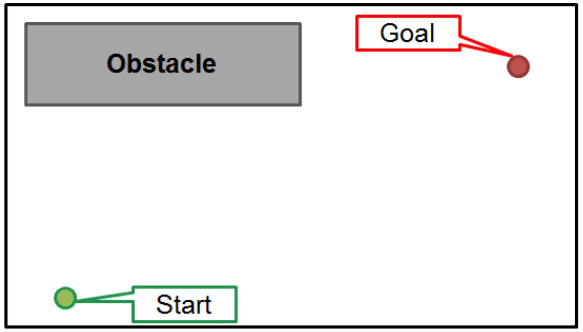
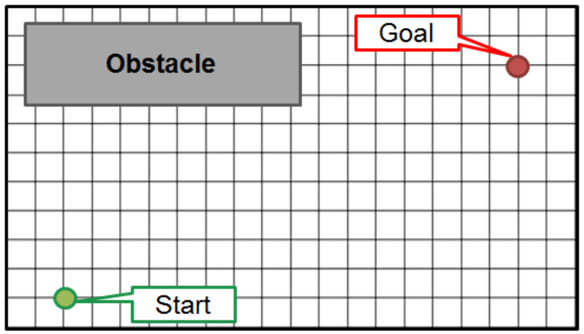
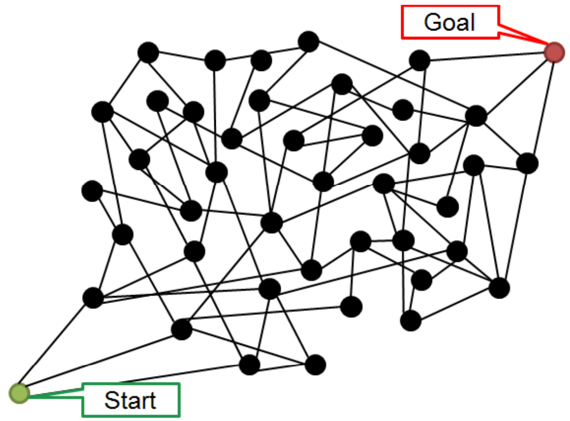




Directed and Weighted Graph



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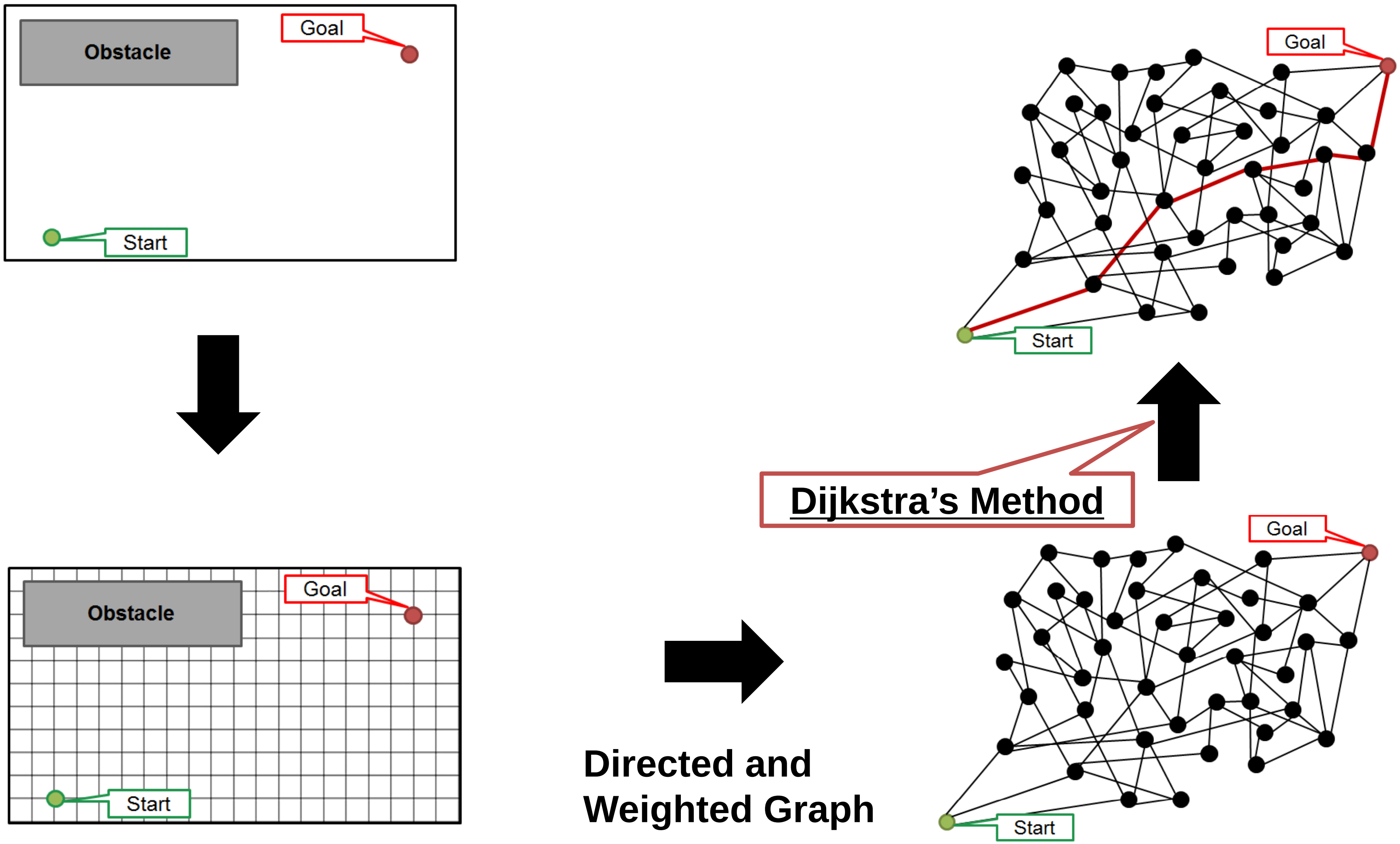

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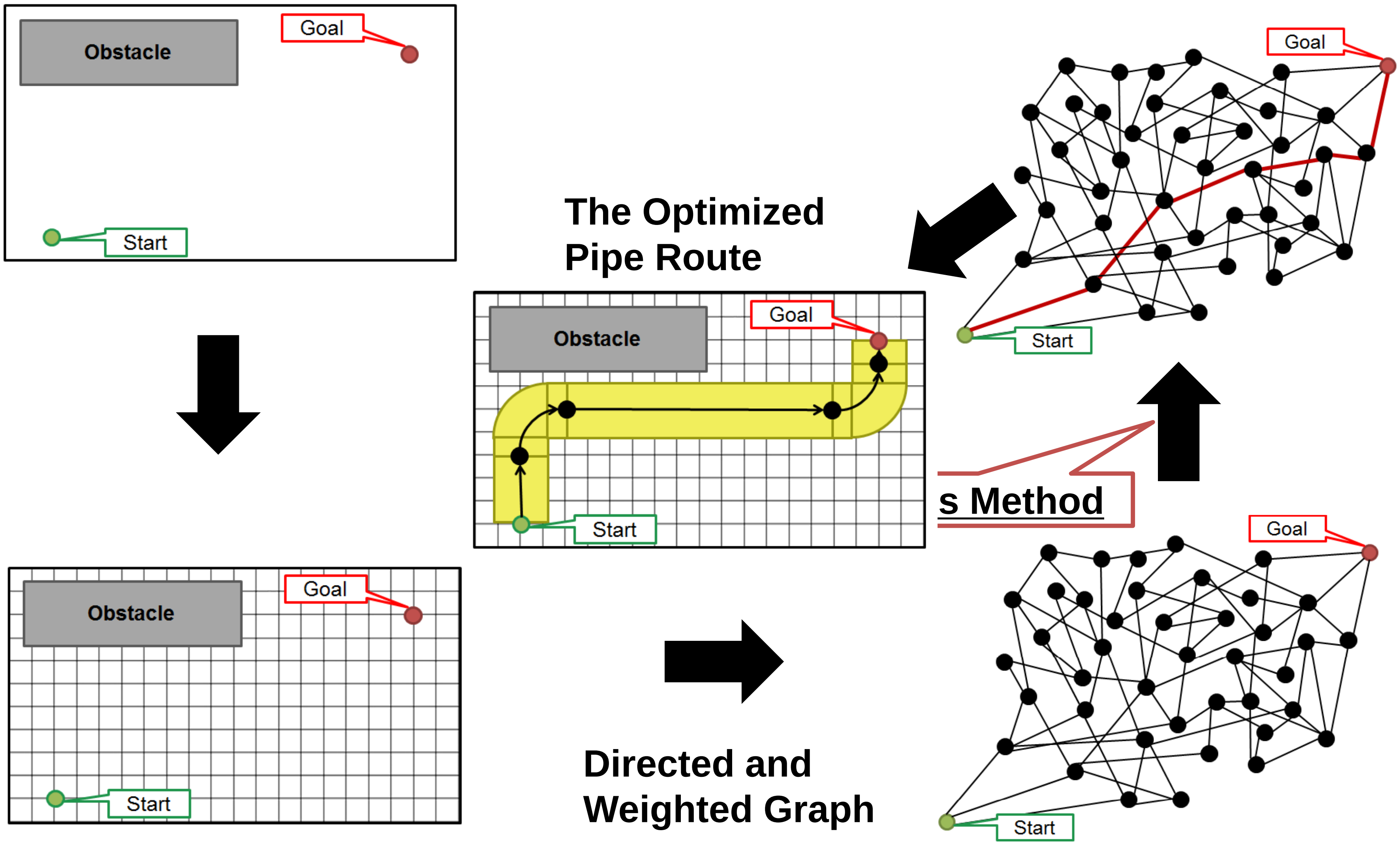
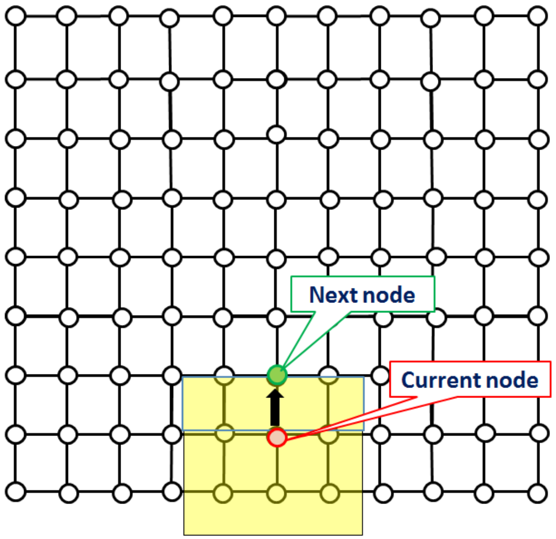
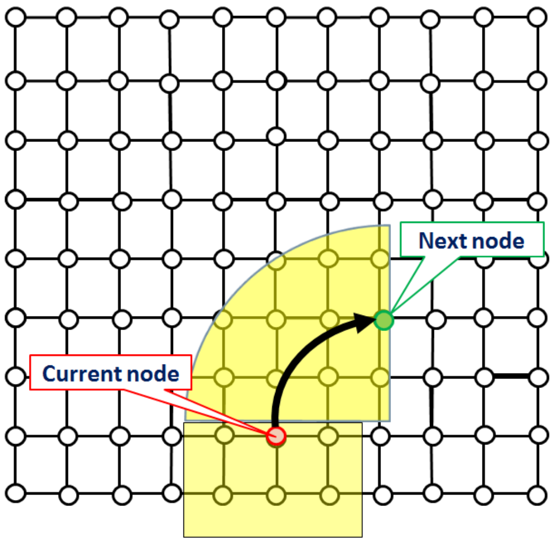


Pipe Pieces and Items

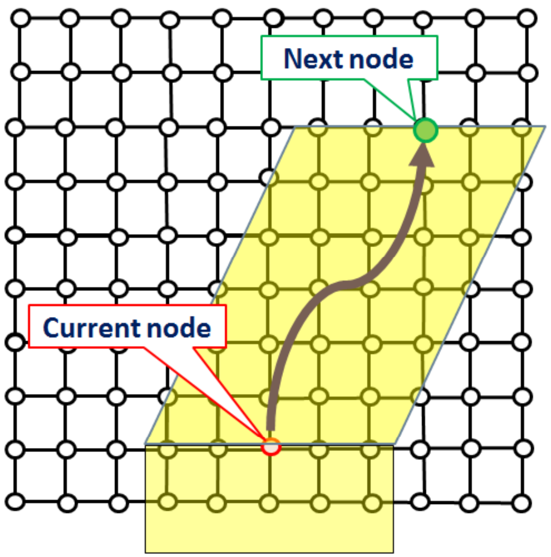
Pipe Pieces



Straight



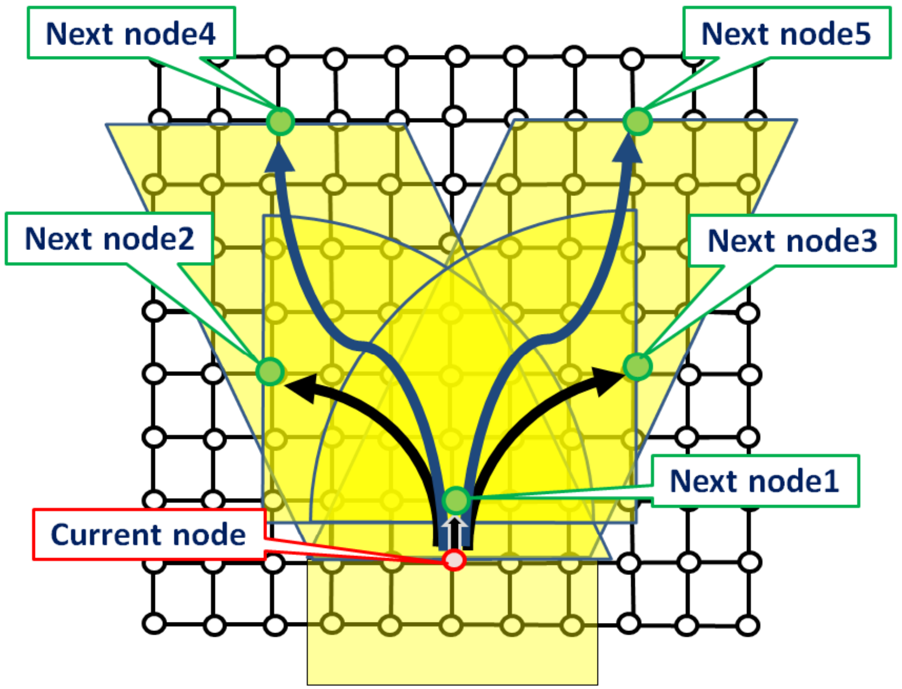
Elbow



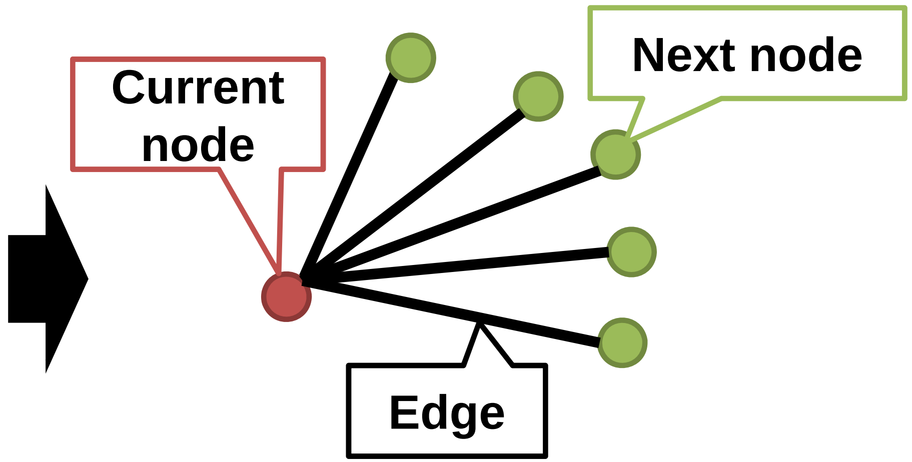
<u>Bending Part</u>

Pipe Pieces and Items

Pipe Pieces



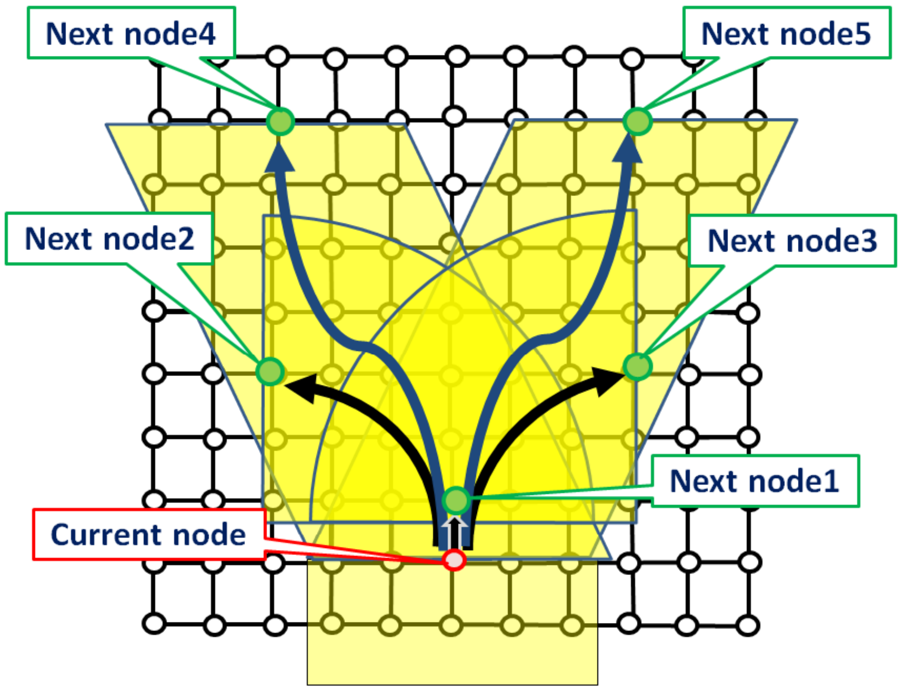
In the graph



Weight of the Edge = (Manhattan distance + Costs of the Pipe Piece) x Diameter

Pipe Pieces and Items

Pipe Pieces



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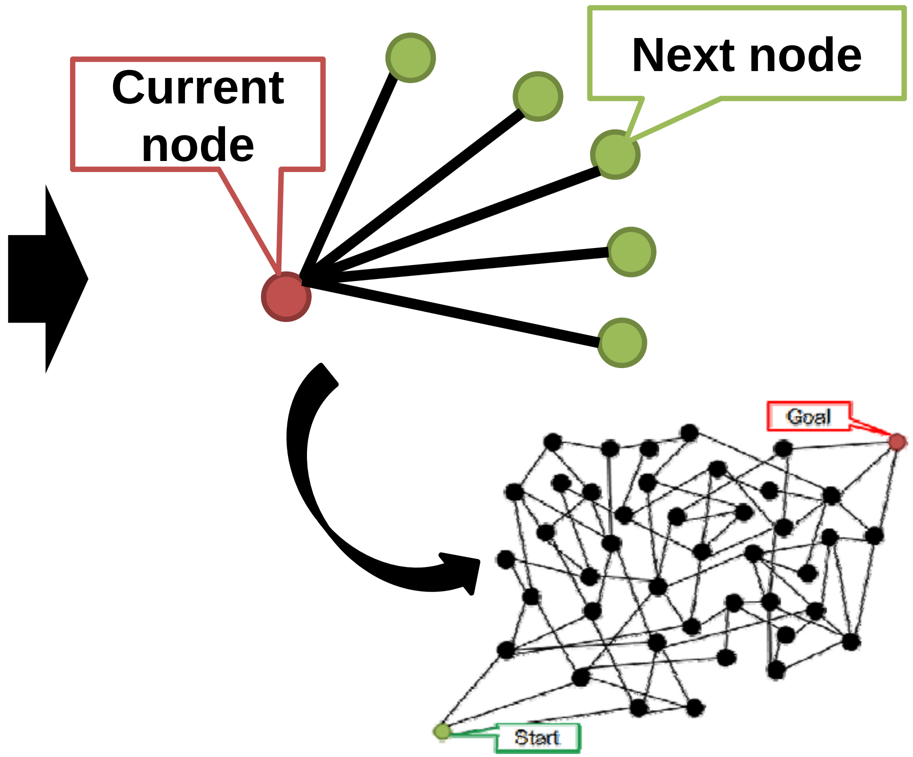
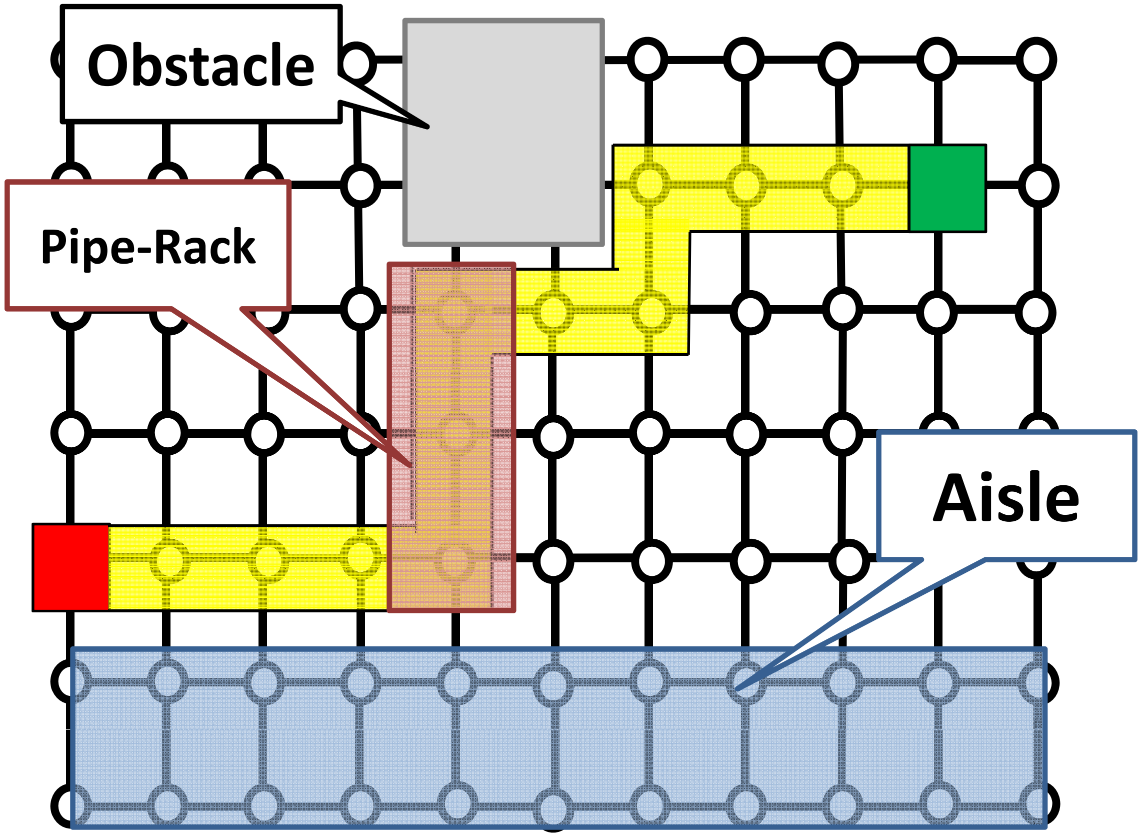


Weight of the Edge = (Manhattan distance + Costs of the Pipe Piece) x Diameter

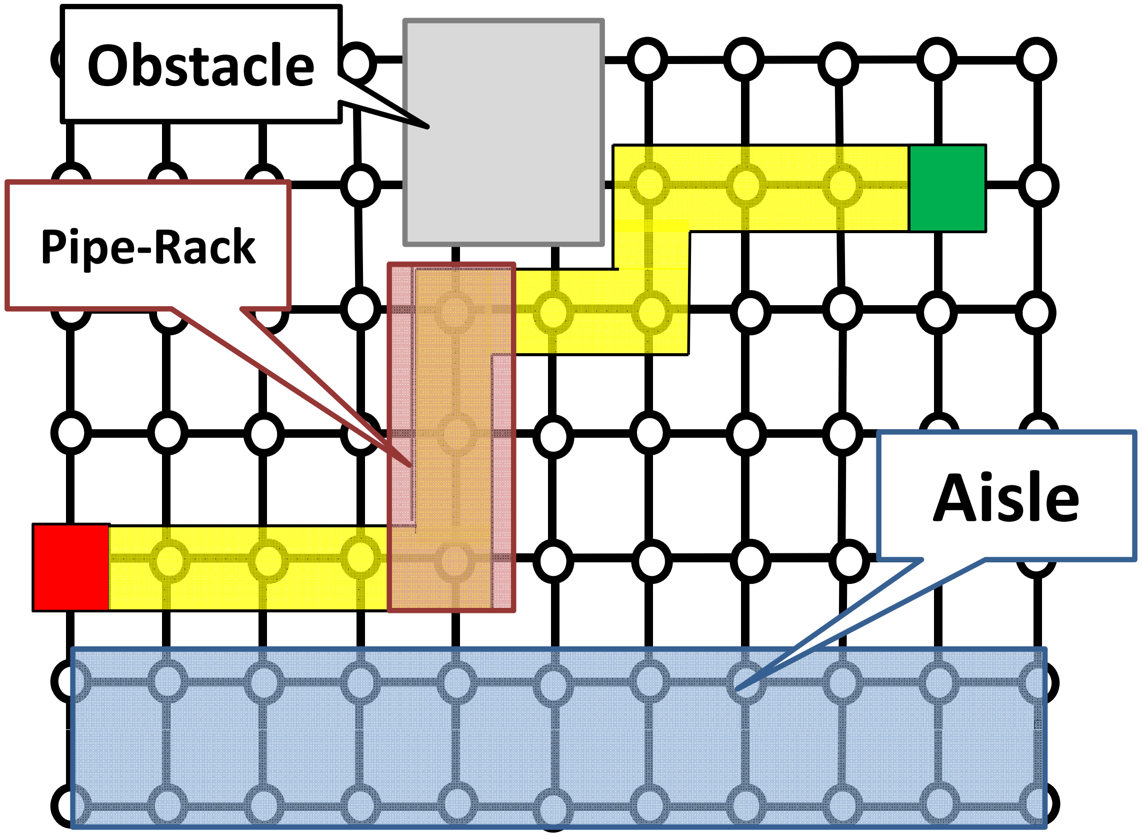
Design Objectives



The shortest path on the network

- **Short**
- **Not winding**
- Avoid aisles
- Set on pipe racks

Design Objectives

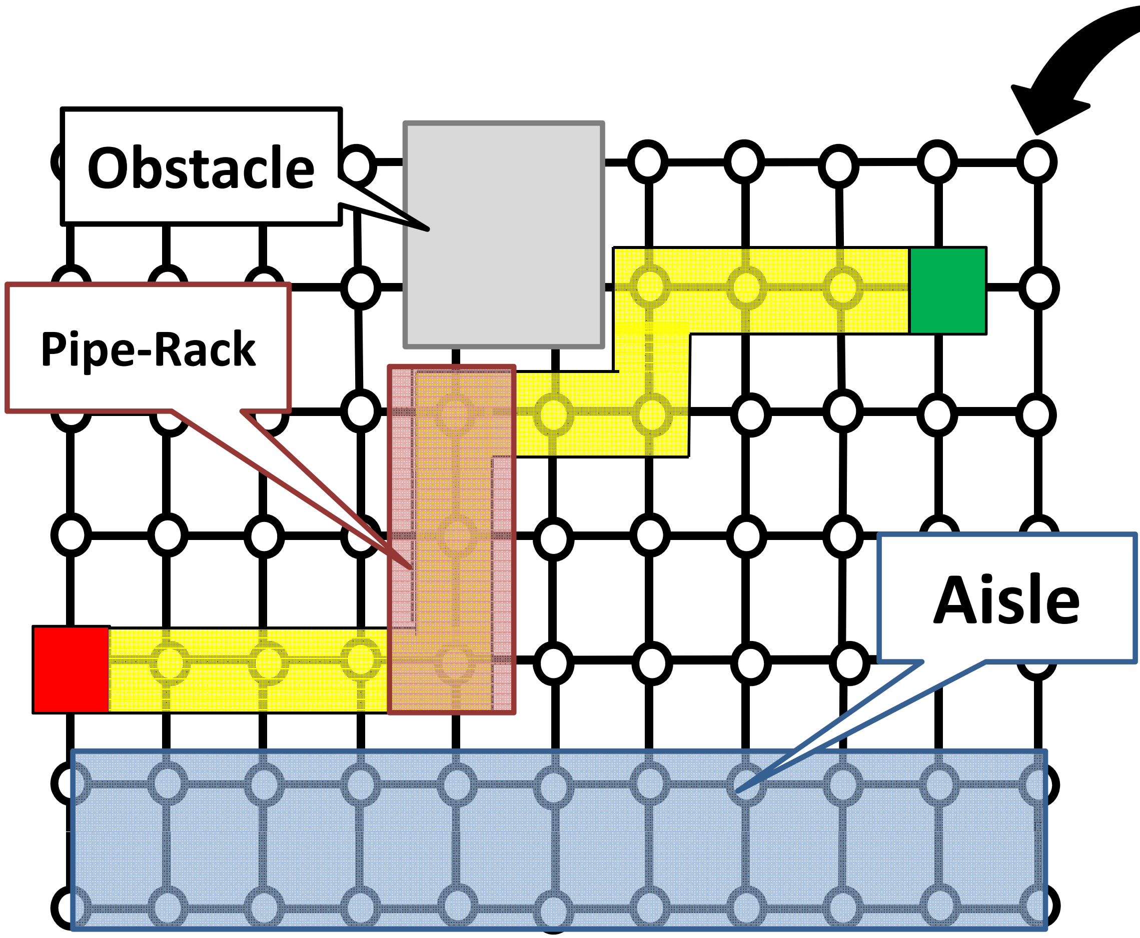


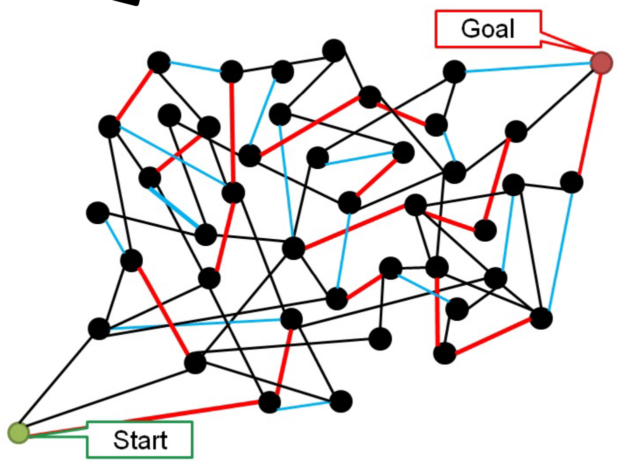
The shortest path on the network

- **Short**
- **Not winding**
- **Set on pipe racks**
- **Avoid aisles**

Change the weight of edges

Design Objectives





: **Light weighted edge (= Pipe-rack)**

: **Heavy weighted edge (= Aisle)**

Design Objectives

- **Minimize the total length of piping routes**
- **Minimize the number of elbows and bending parts**
- **Avoid aisles as much as possible**
- **Pass through pipe-rack areas as much as possible**

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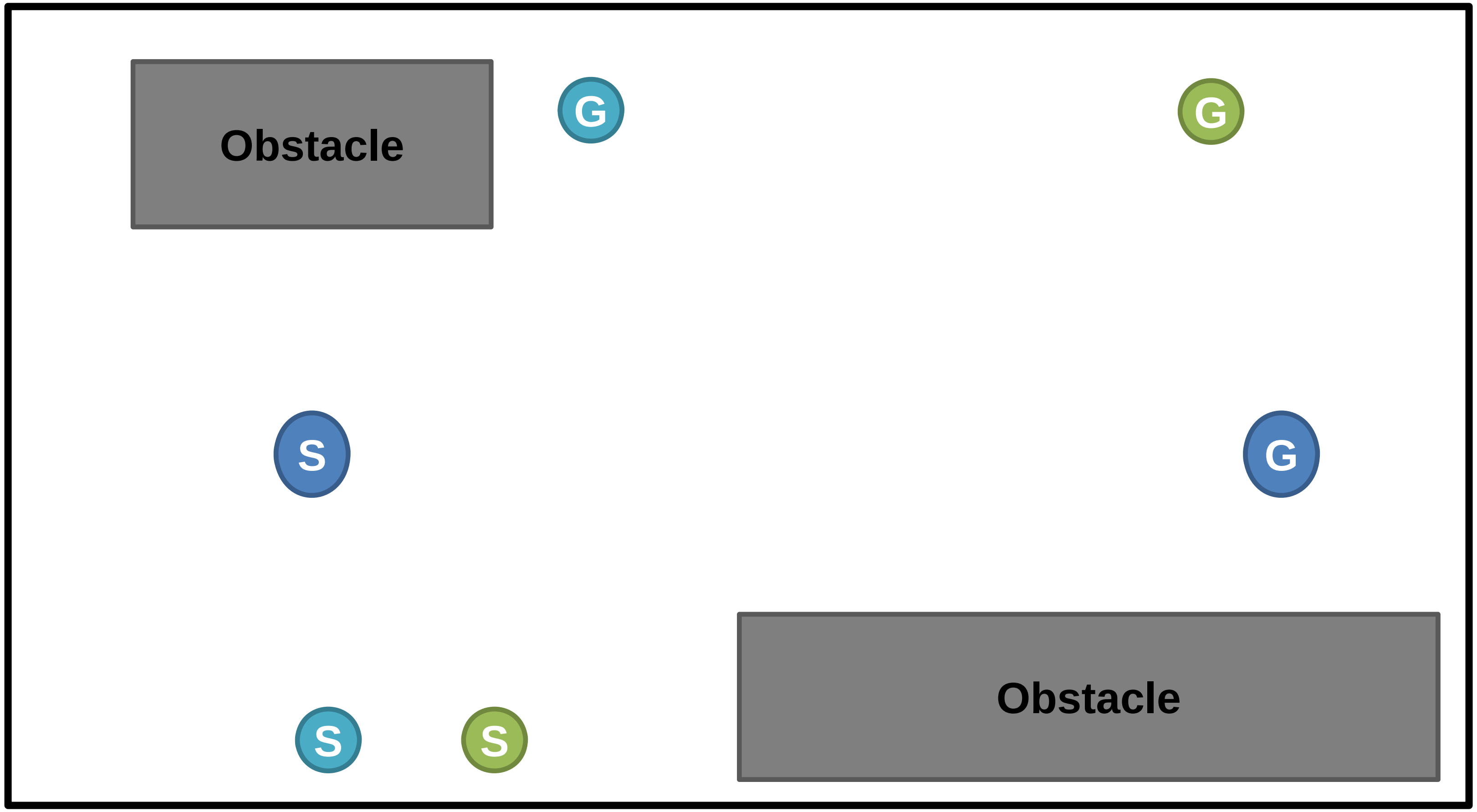
= The shortest path in the weighted graph

Order of Routing

Order of routing in the system = <u>From the largest to the smallest</u>



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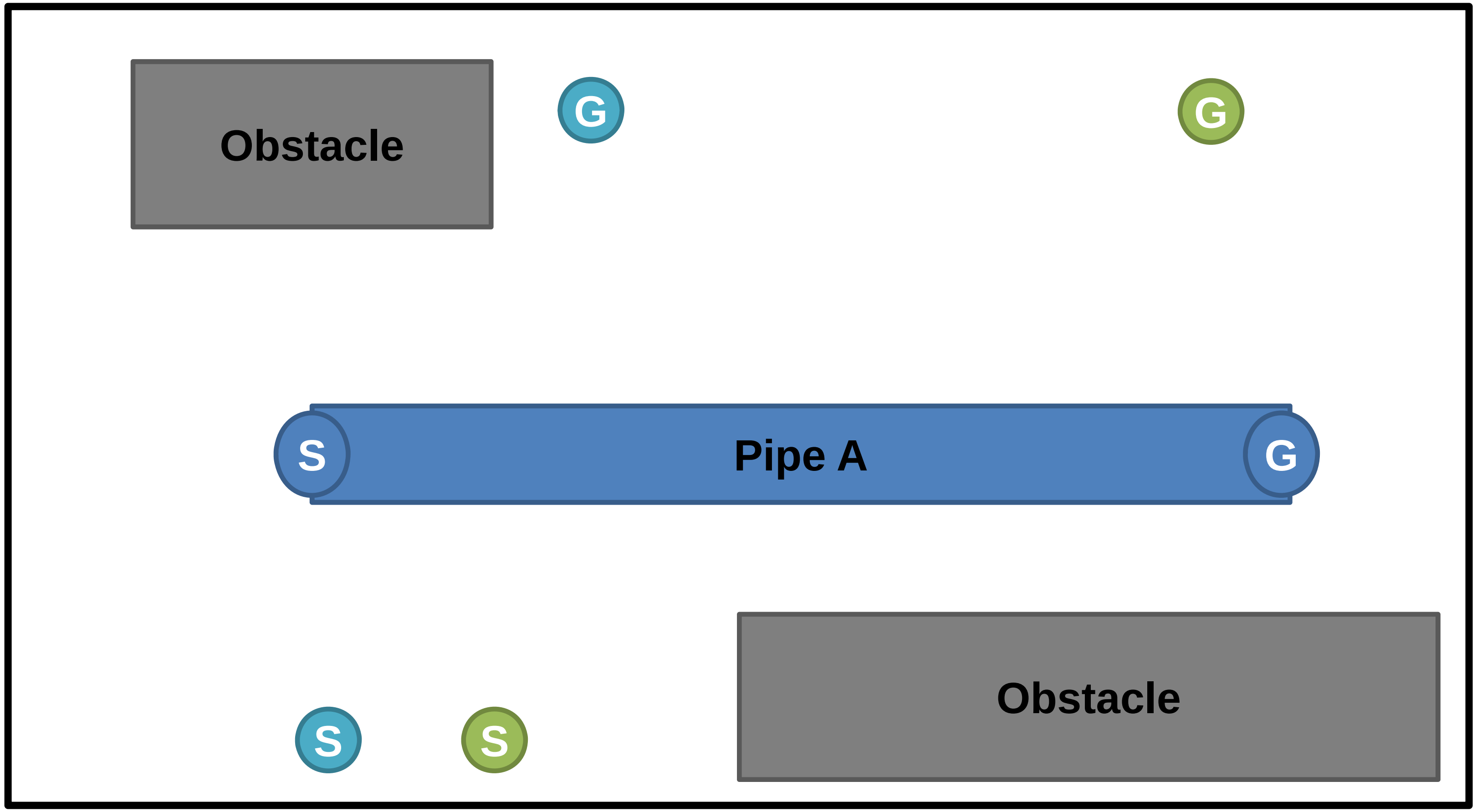

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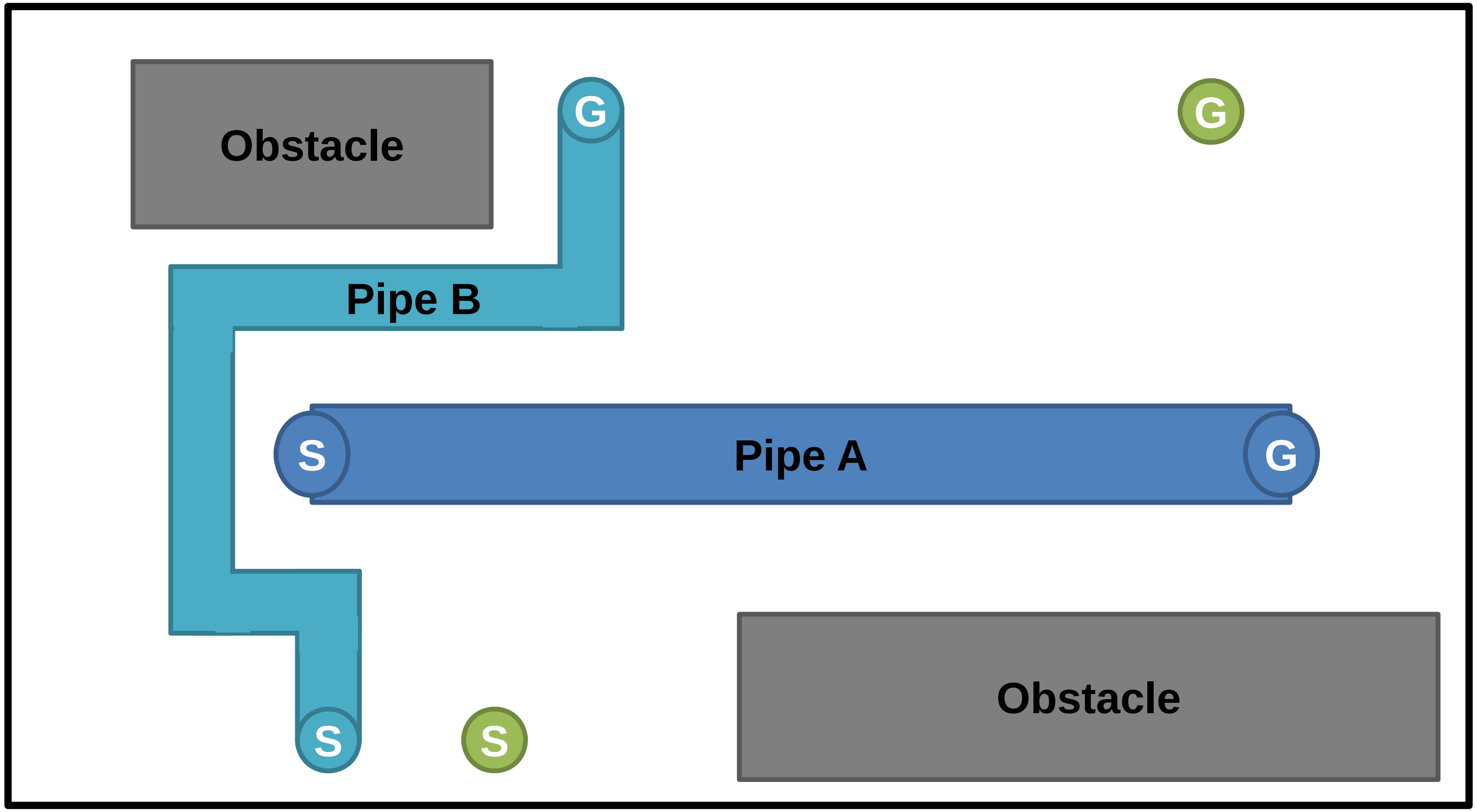

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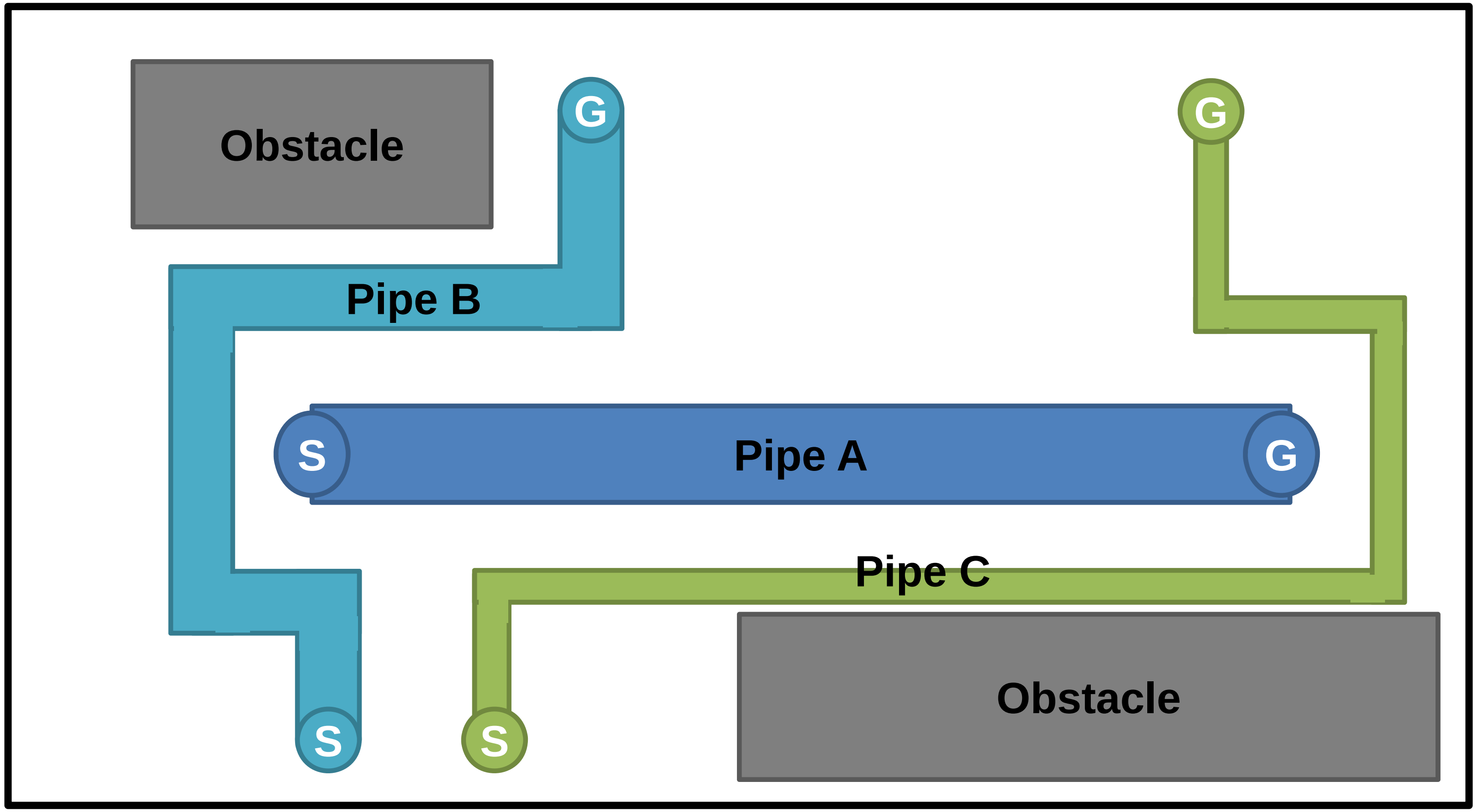
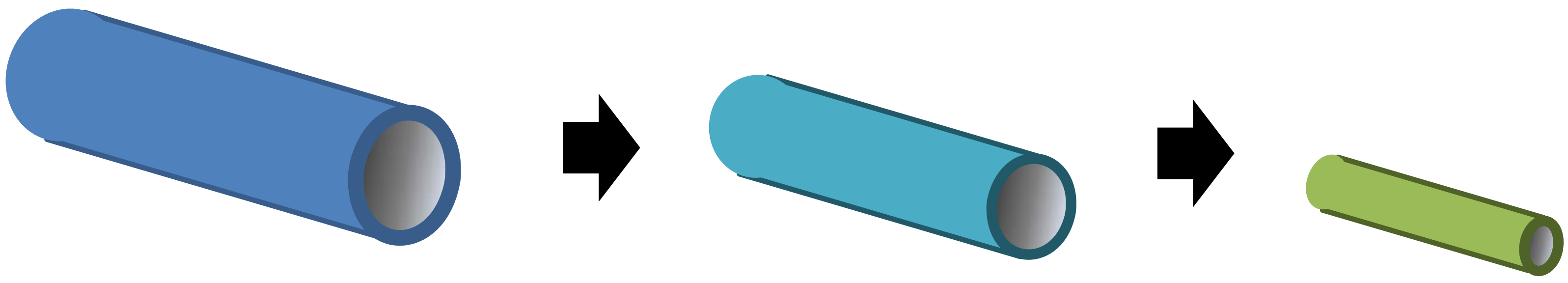
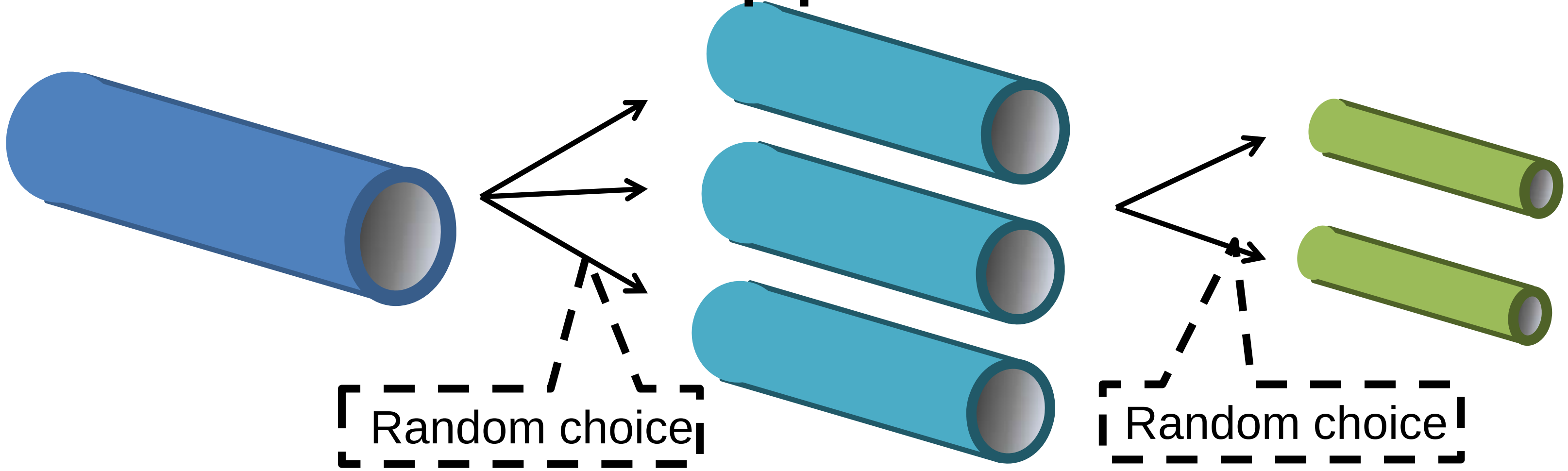


Order of Routing

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



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



Outline

◆ Introduction

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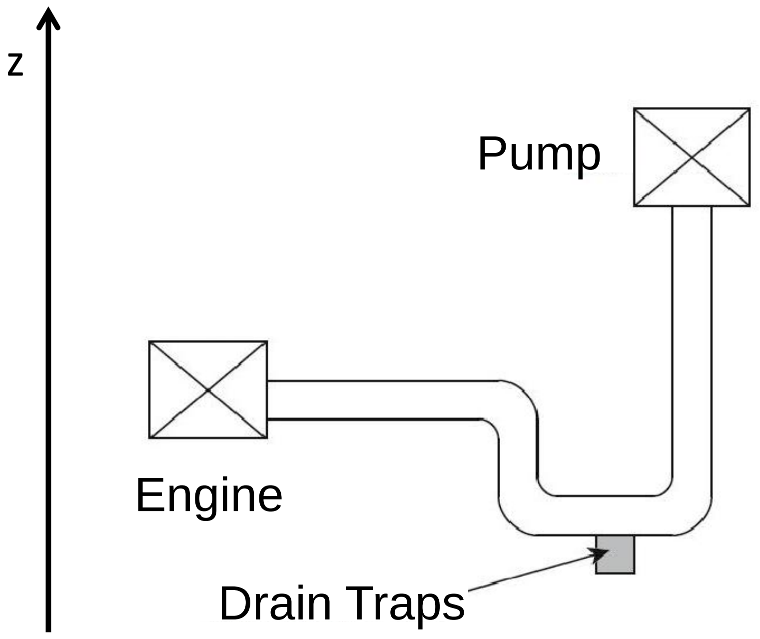
3. Simulations

◆ Conclusion

What's "Pocket" ?

- **U-shaped pipe piece <u>in a vertical direction</u>**
- **Liquid or gas settle at "Pocket"**

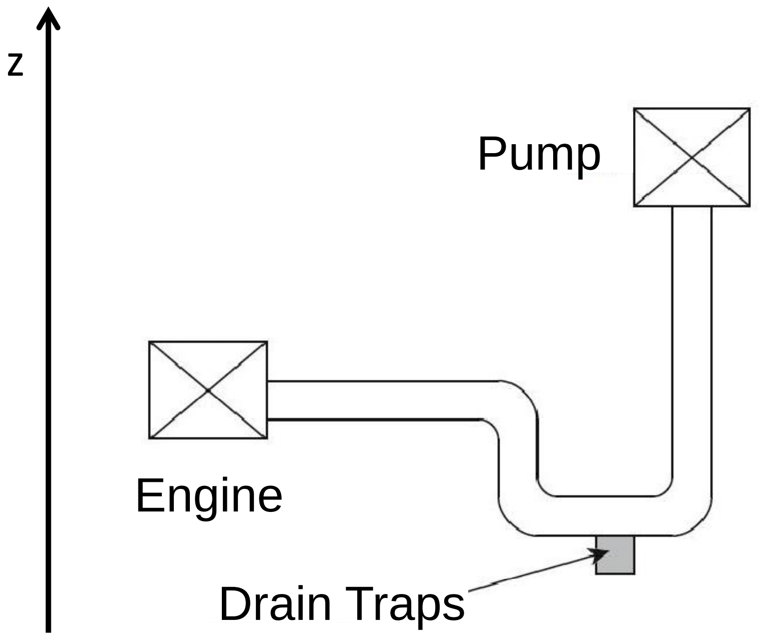


What's "Pocket" ?

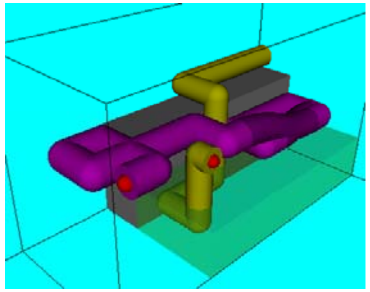
- **U-shaped pipe piece <u>in a vertical direction</u>**
- **Liquid or gas settle at "Pocket"** → **Drain traps**

↓

<u>Undesirable pipe piece</u>



Algorithm to avoid "Pockets"



Loading of Start and Goal point

Method1 (Restriction Method) → Found! → **Route without pockets**

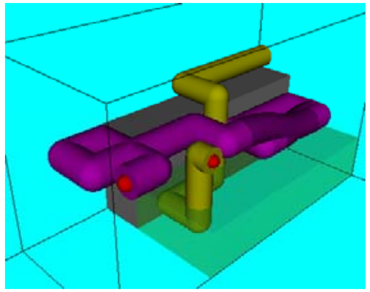
↓ Not Found… : At least one pocket in the route

Method2 (Penalty Method) → Found! → **Route avoiding pockets as much as possible**

↓ Not Found…

No pipe route

Algorithm to avoid “Pockets”



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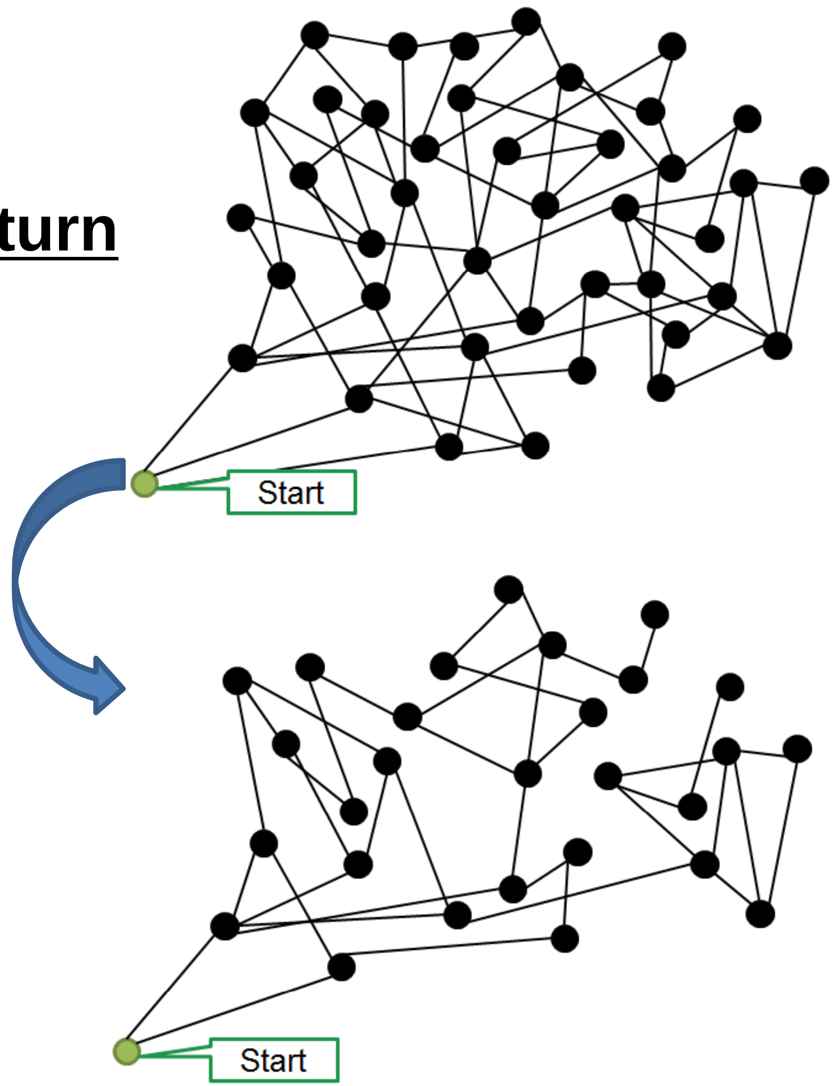
No pipe route

Method1: Restriction Method

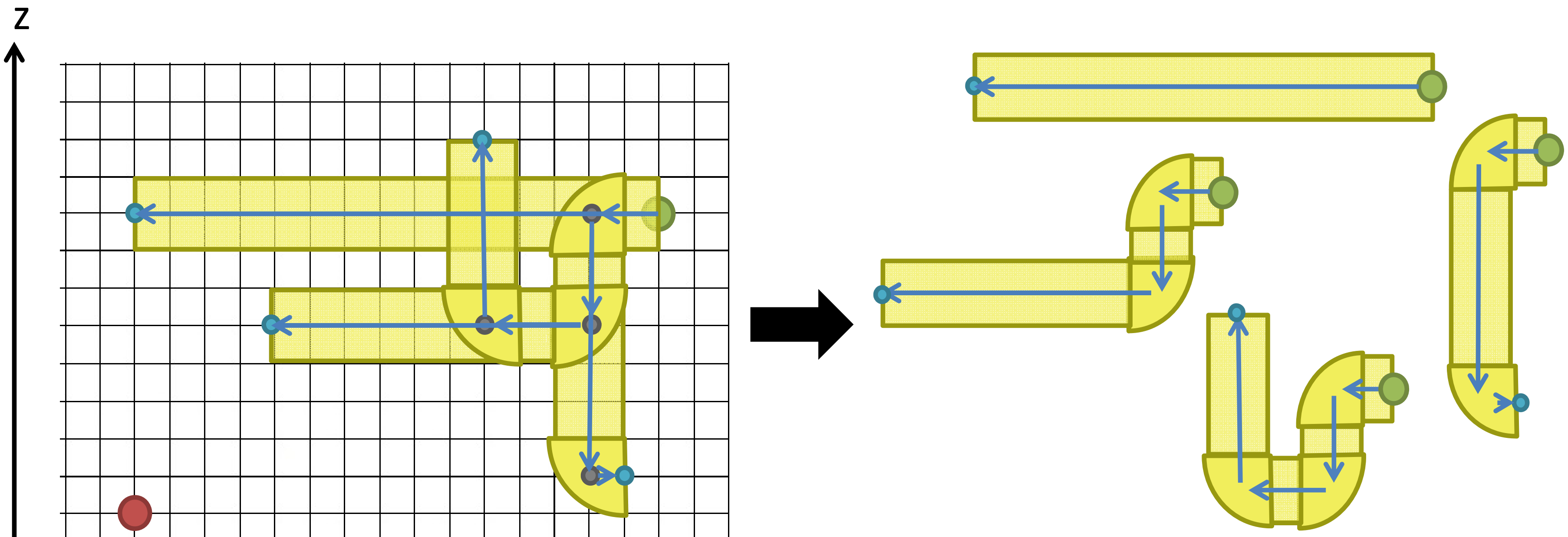
Restriction Method

- **Delete candidates making U-turn**
- **Reduce size of network**

No pocket in the route

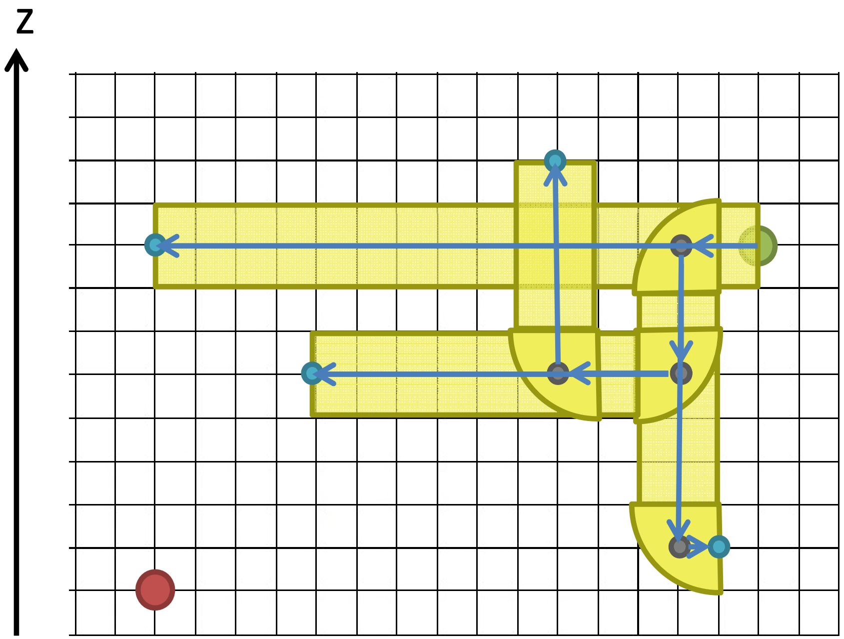


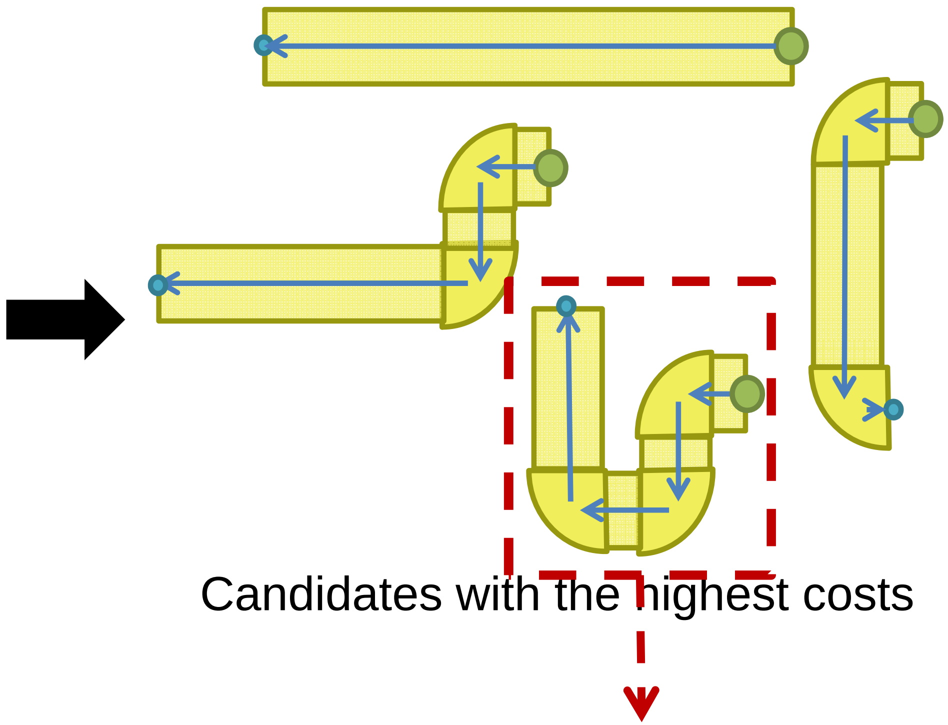
Method1: Restriction Method



Candidates with the highest costs

Method1: Restriction Method

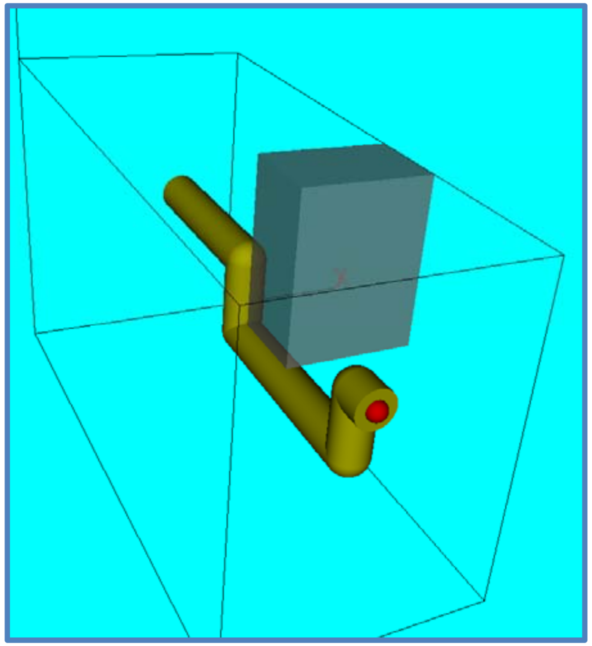




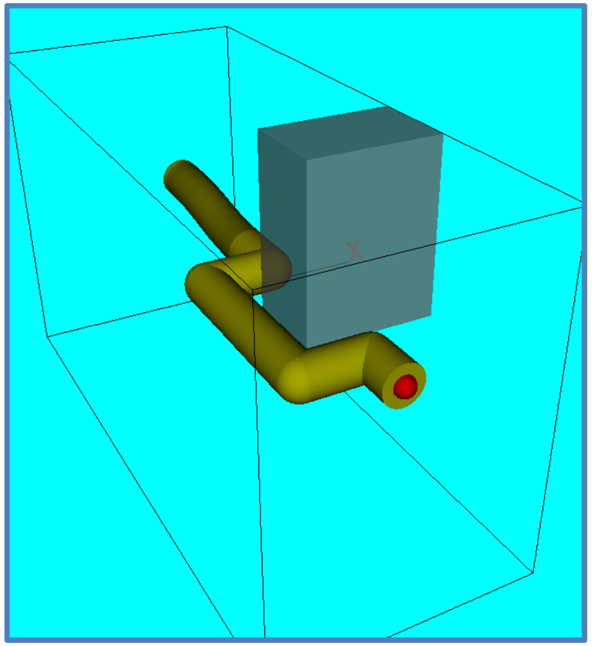
Candidates with the highest costs

Route without "Pockets" ⟵ **<u>Remove from candidates</u>**

Simulation of Restriction Method



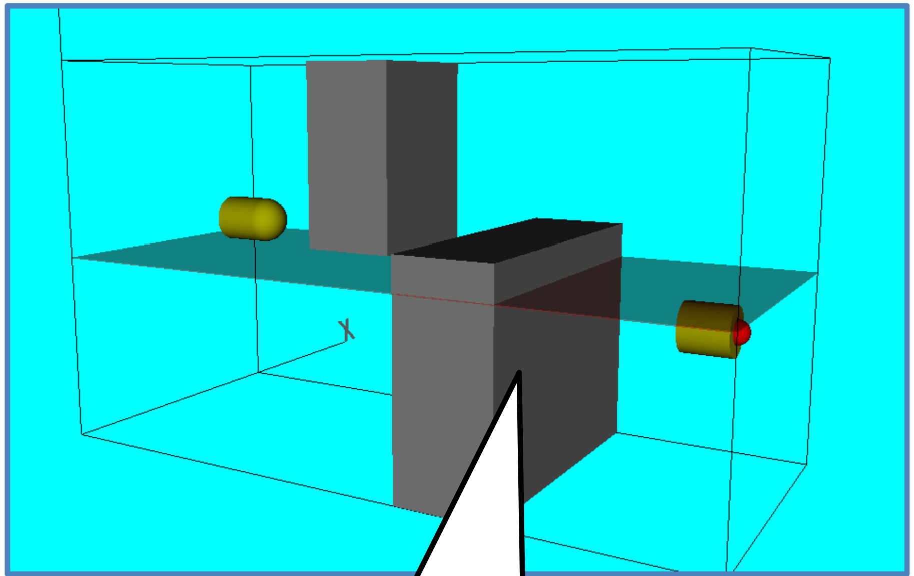
Solution by Old System
(Without consideration of Pockets)



Solution
by Restriction Method

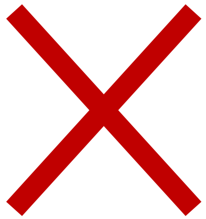
Simulation of Restriction Method

Other test case…



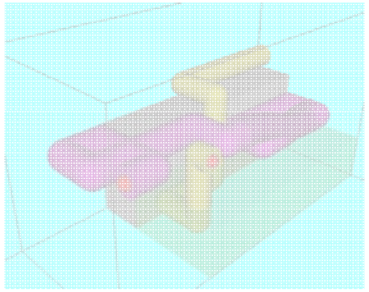
Pocket is necessary

Complex route
(Route with at least one Pocket)



No solution
by Restriction Method

Algorithm to avoid "Pockets"



Loading of Start and Goal point

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Method1 (Restriction Method) —Found!→ **Route without pockets**

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Method2 (Penalty Method) —Found!→ **Route avoiding pockets as much as possible**

↓ Not Found…

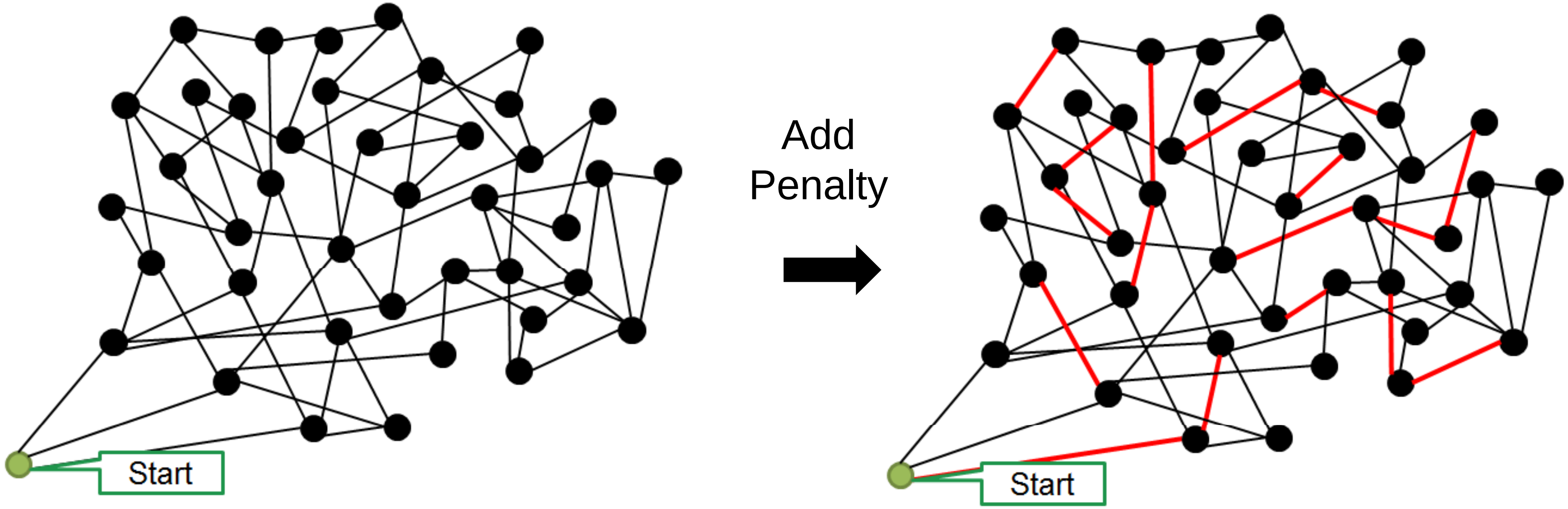
No pipe route

Method2 : Penalty Method

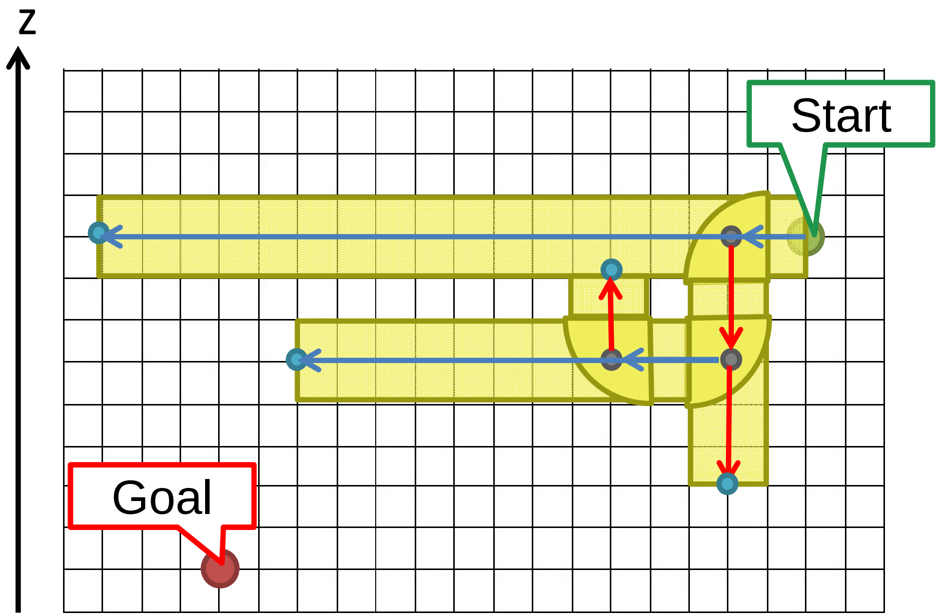
Penalty Method

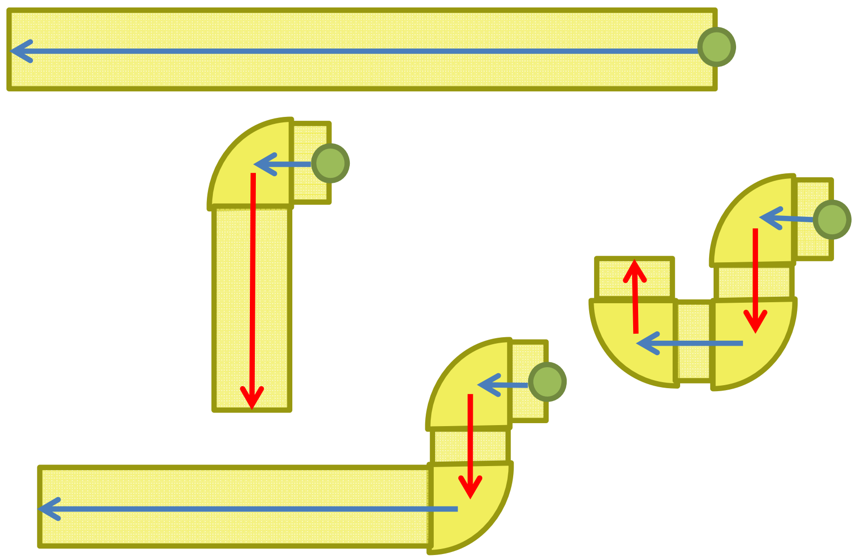
- **<u>Add penalties</u> on edges connecting vertically.**
- **Search horizontal candidates as priority.**

<u>Route involves "Pockets" as few as possible.</u>



Method2 : Penalty Method

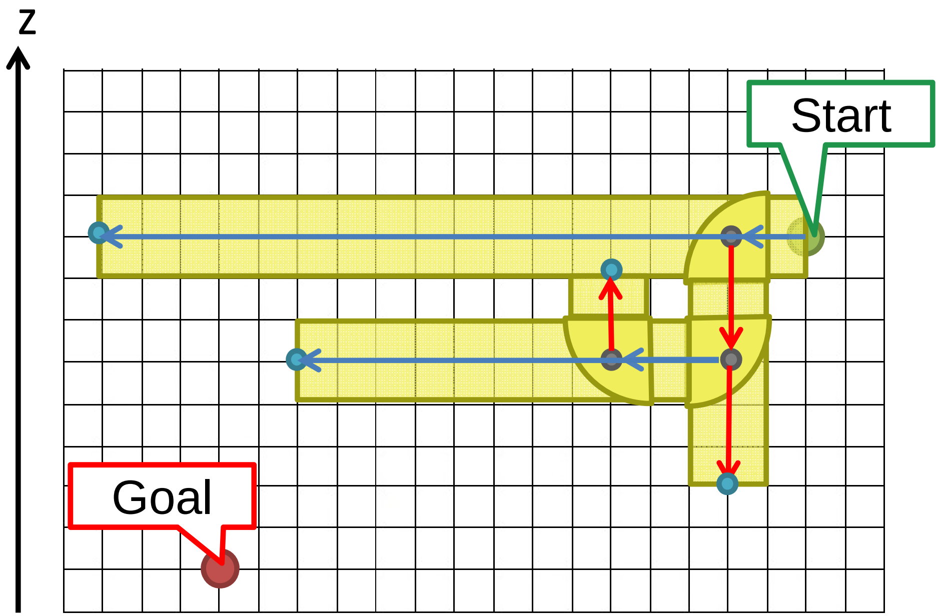


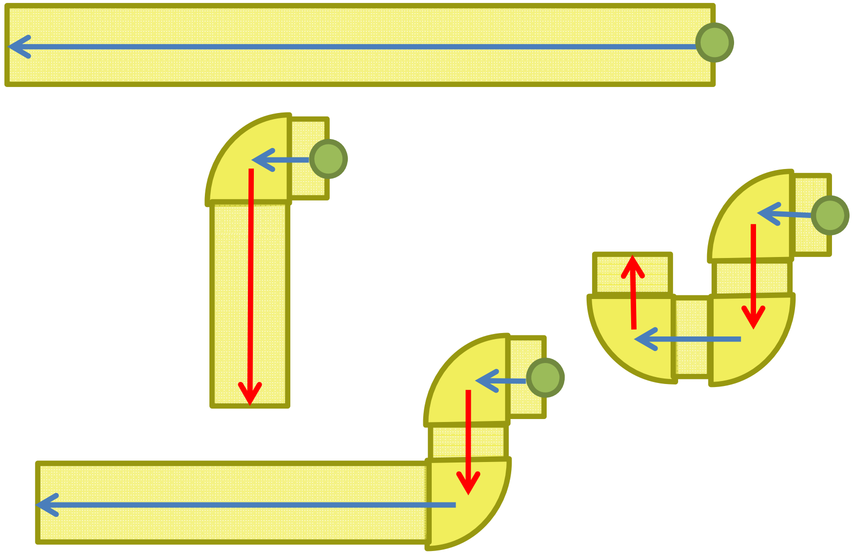


Red arrows : With penalties
Blue arrows : Normal

Candidates with the highest costs

Method2 : Penalty Method





Red arrows : With penalties
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Candidates with the highest costs

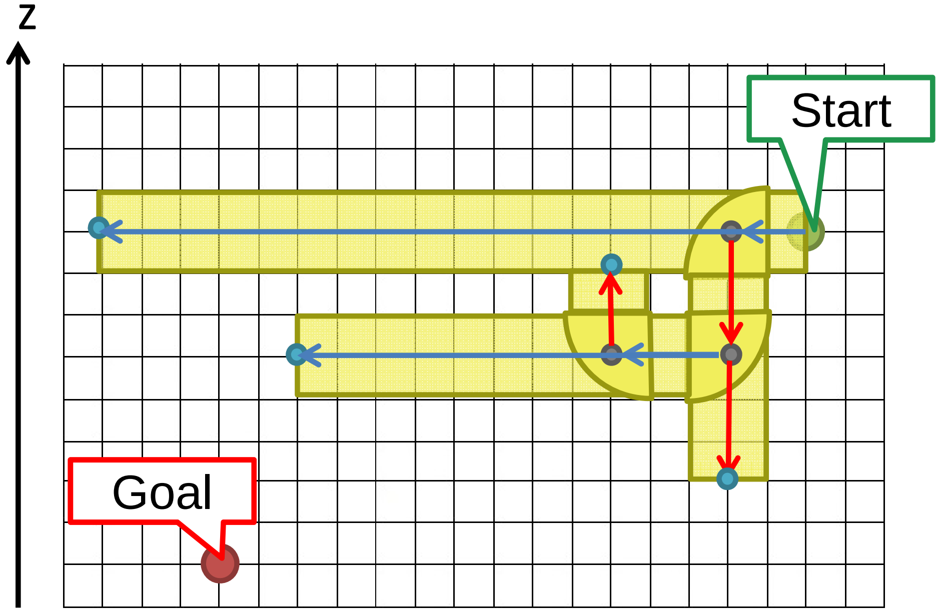
↓

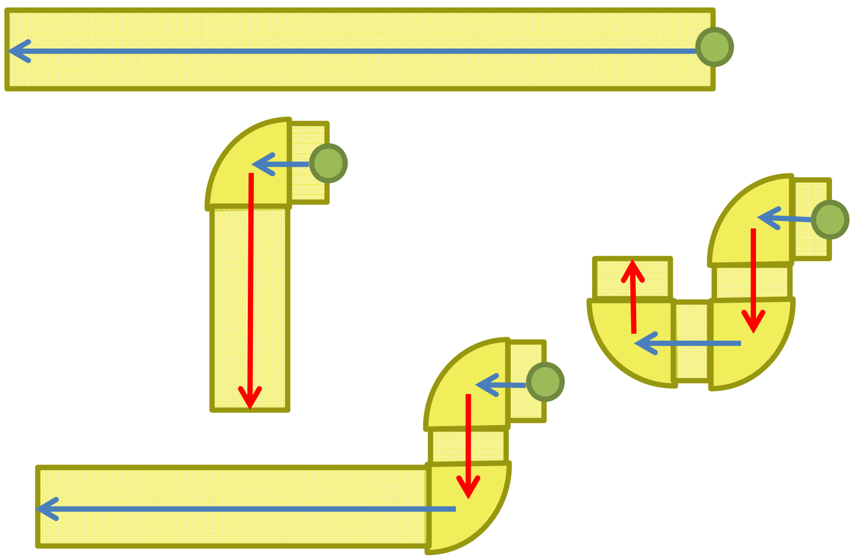
<u>Avoid moving vertically as much as possible</u>

↓

Route avoiding Pockets as much as possible

Method2 : Penalty Method





Red arrows : With penalties
Blue arrows : Normal

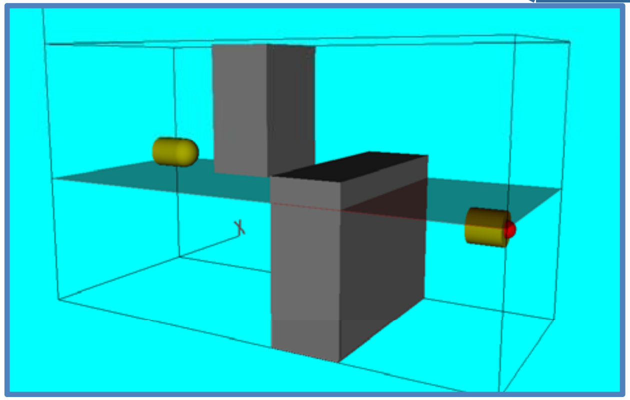
Candidates with the highest costs

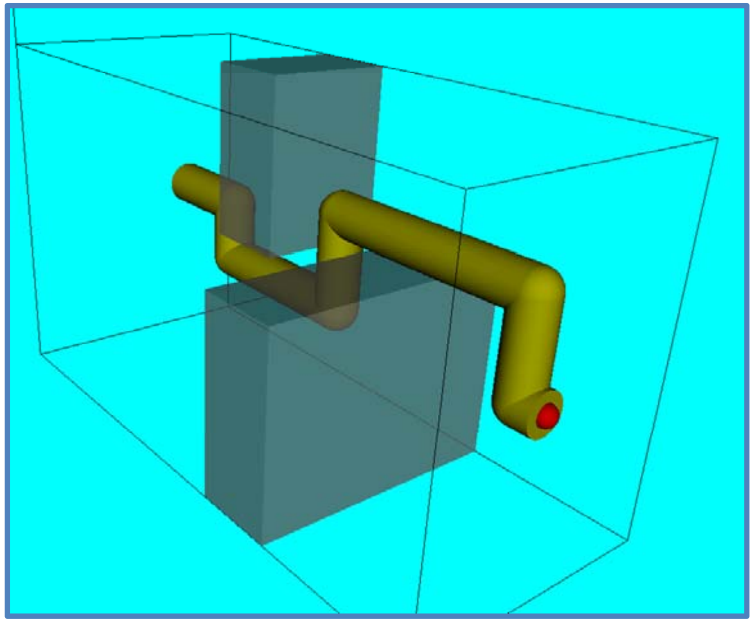
Avoid moving vertically as much as possible

Increase of search time

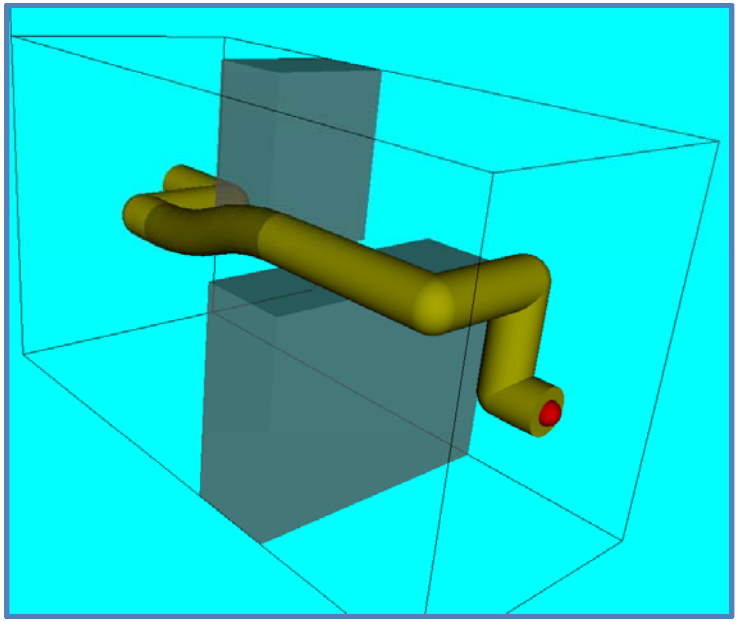
Route avoiding Pockets as much as possible

Simulation of Penalty Method





Solution by old System



Solution by Penalty Method

Outline

- Introduction

1. Approach

2. Air Pockets

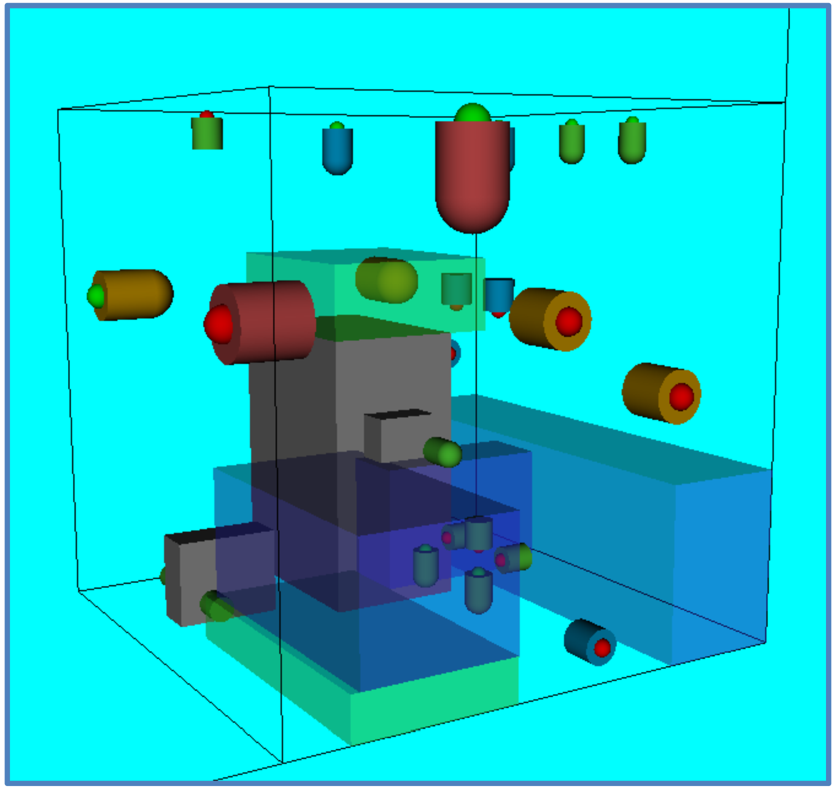
3. Simulations

- Conclusion

Simulations

Purpose of simulations

Comparisons of old and new Systems, different mesh sizes, and orders of routing

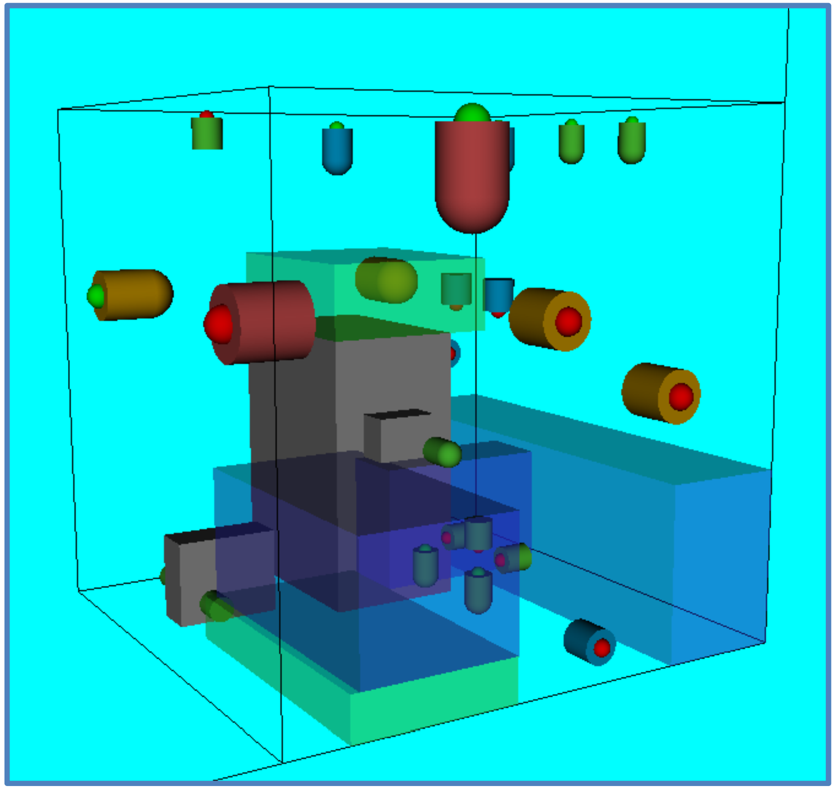


Simulations

Purpose of simulations

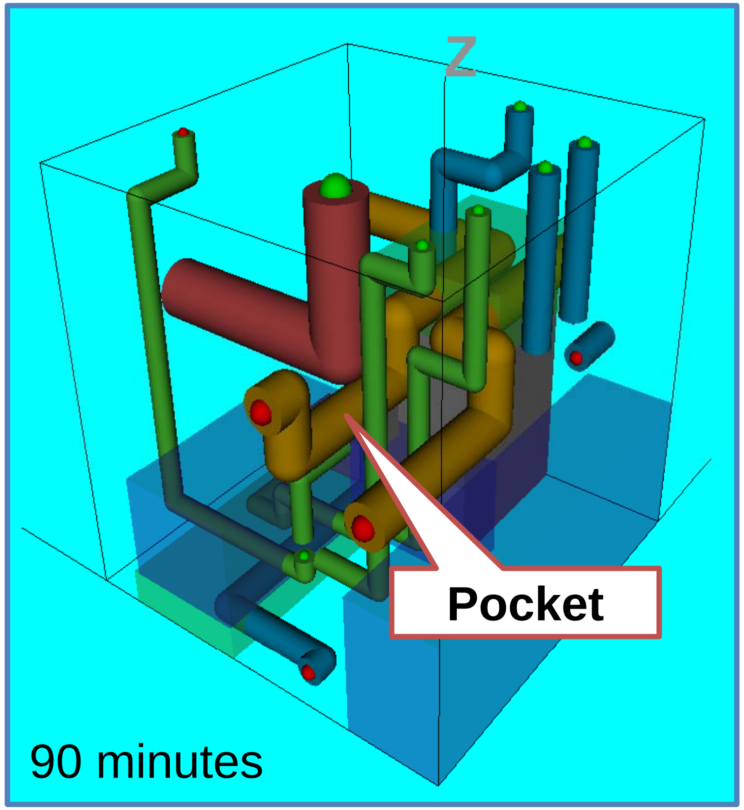
Comparisons of old and new Systems, different mesh sizes, and orders of routing

Test model

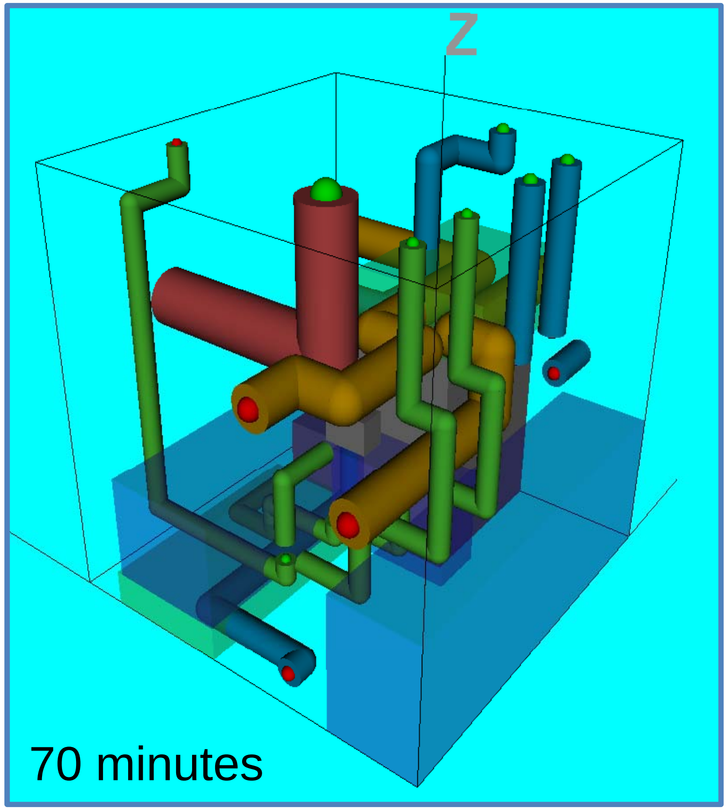


- Design Space : 6 x 6 x 6 [m]
- Pipes : ϕ 0.8[m] x 1, ϕ 0.6[m] x 2, ϕ 0.4[m] x 4, ϕ 0.3[m] x 6
- Order : From the largest pipe
- Cost of Elbow : 0.1
- Cost of Bending : 0.3
- <u>Penalty of vertical edge : x2</u>

Simulation1 (Comparison of Old and New Systems)



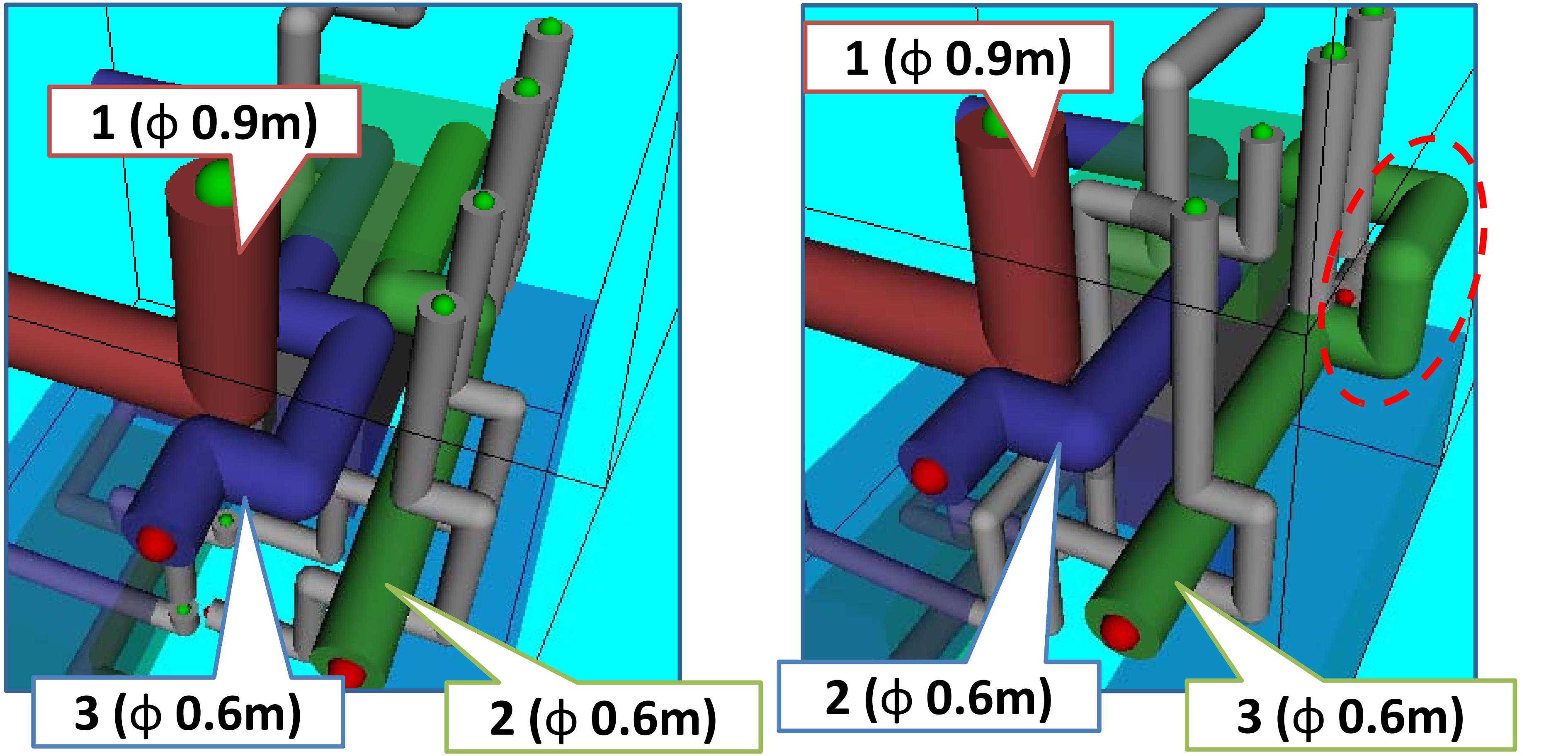
Old System
(Without consideration of Pockets)



New System
(With Method 1 and 2)

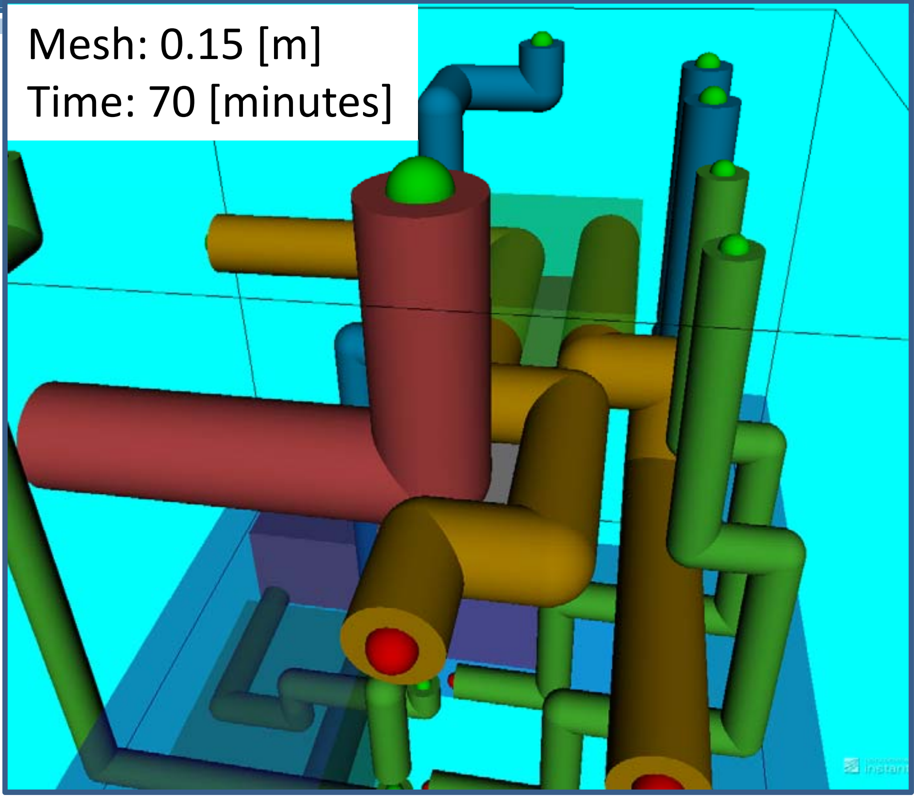
Succeeded to avoid making Pockets

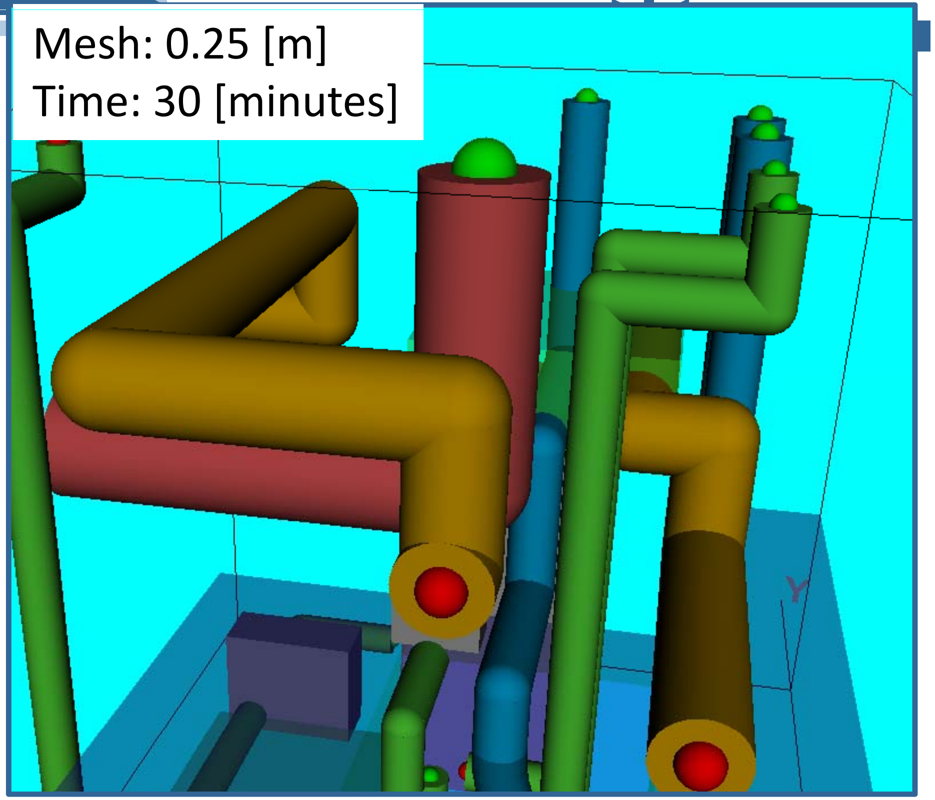
Simulation2 (Comparison of different orders)



Order of routing: Strong influence to the final design.

Simulation3 (Comparison of mesh sizes)





Small Mesh Size

- Accurate Routing
- Long Search Time

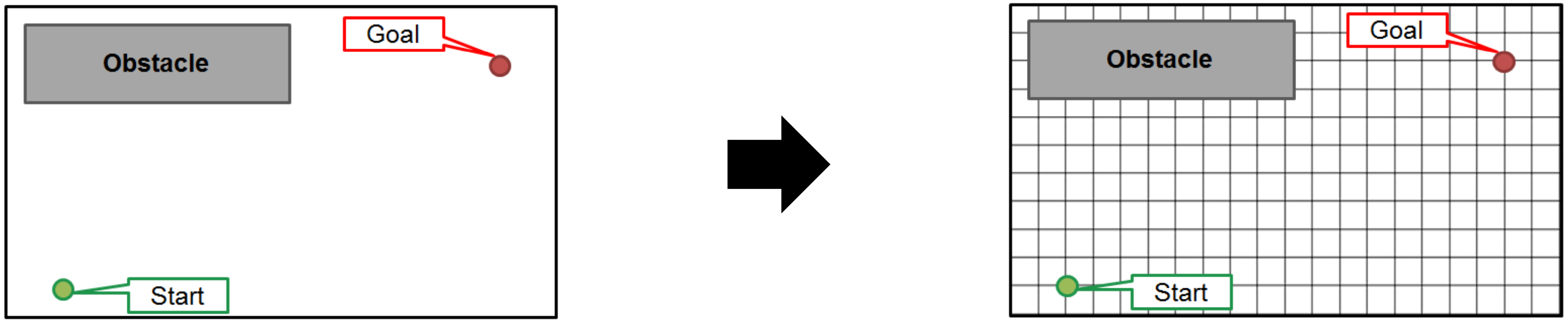
↔

Large Mesh Size

- Rough Routing
- Short Search Time

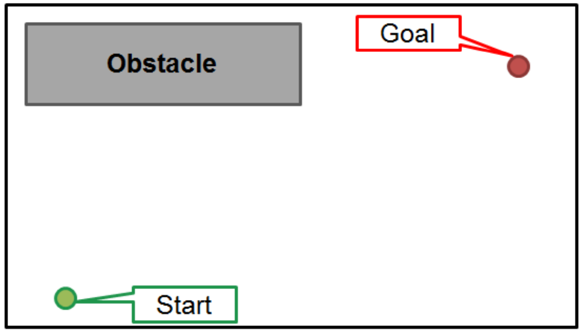
Mesh Size: Strong influence to the routes.

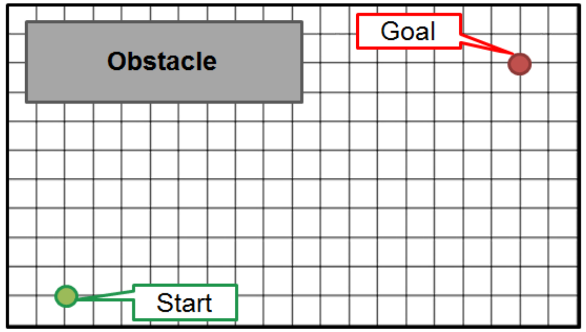
New Mesh Dividing Method



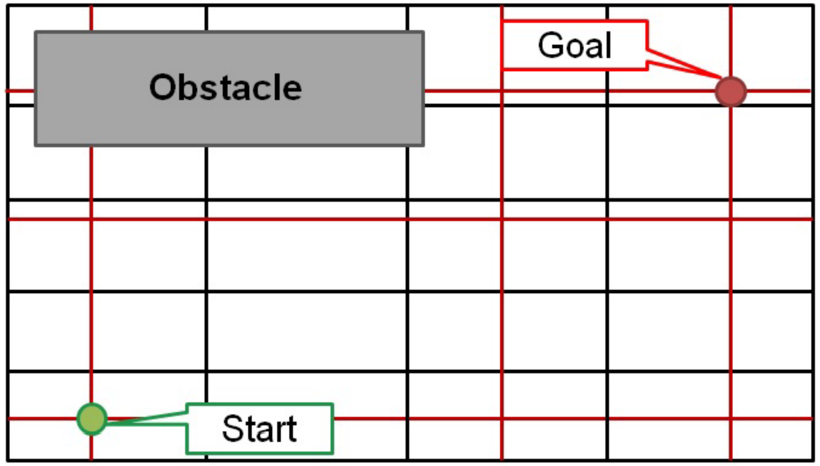
Regular meshes only

New Mesh Dividing Method





Regular meshes only



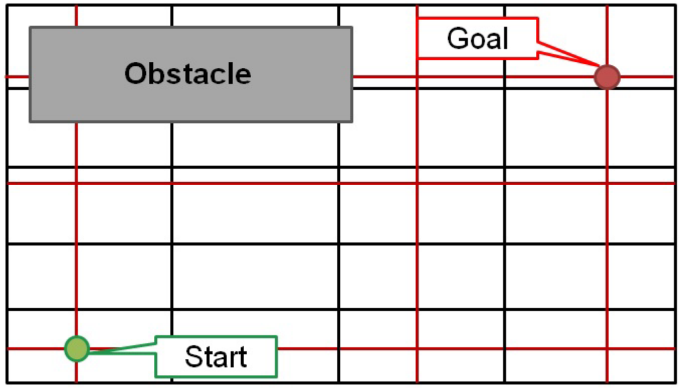
Regular and additional meshes

: Regular Lines

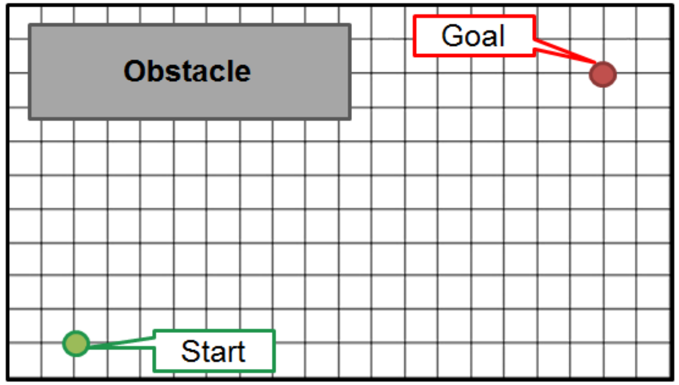
: Additional Lines

- **Around obstacles, pipes, aisles**
- **In pipe-racks**
- **On start and goal points**

New Mesh Dividing Method

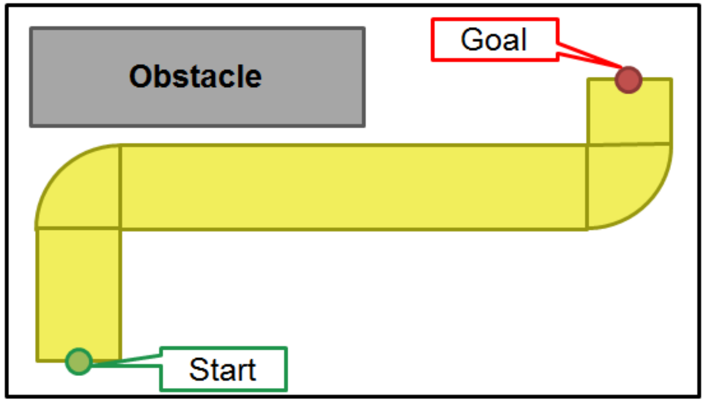


<u>Regular and additional meshes</u>



Regular meshes only

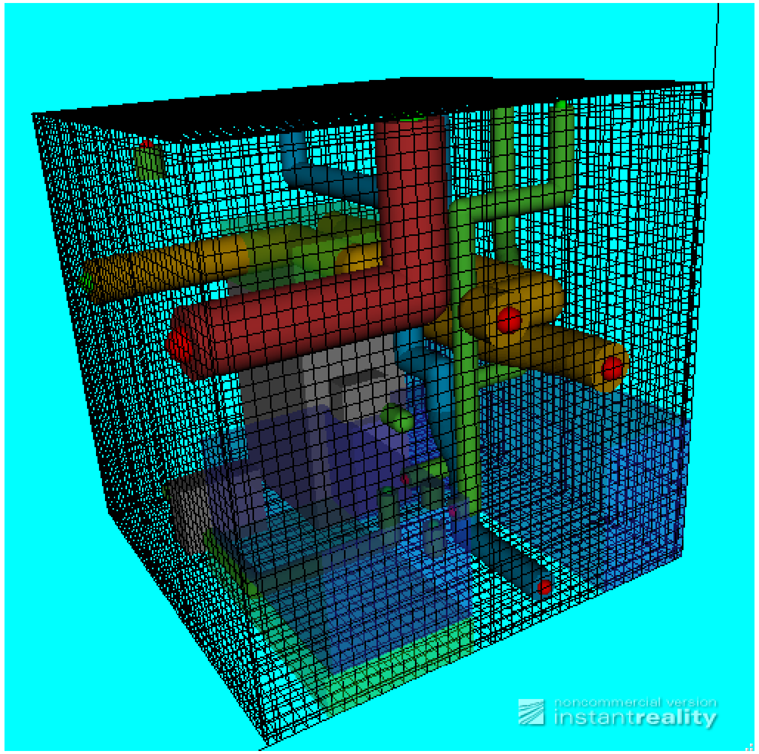
<u>In short time</u>



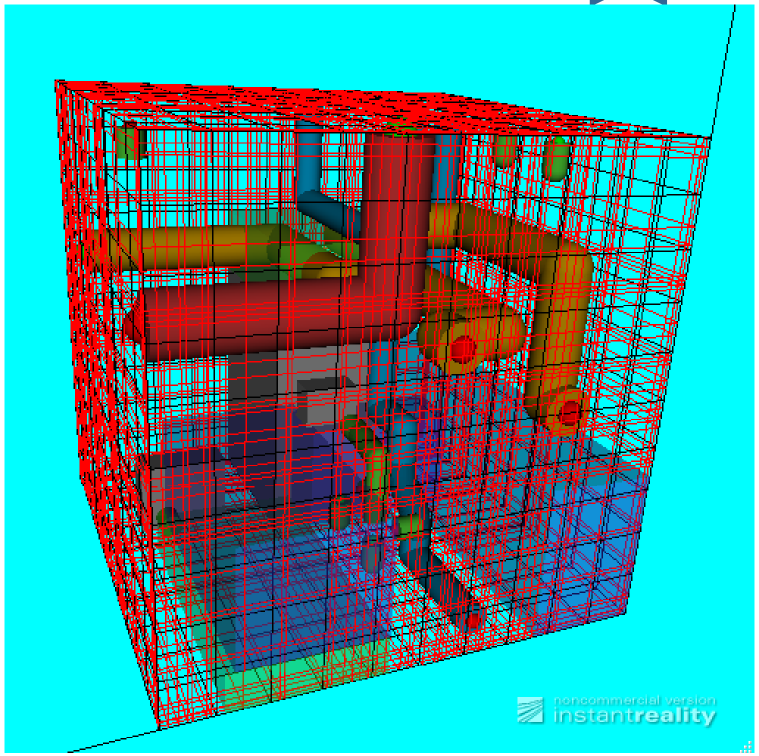
In long time

Increase of items (ex. Obstacles) = <u>Increase of additional meshes</u>

New Mesh Dividing Method



Regular Mesh System



Additional Mesh System

Num. of Meshes in Regular Mesh << Num. of Meshes in Add. Mesh

Increase of search time!!

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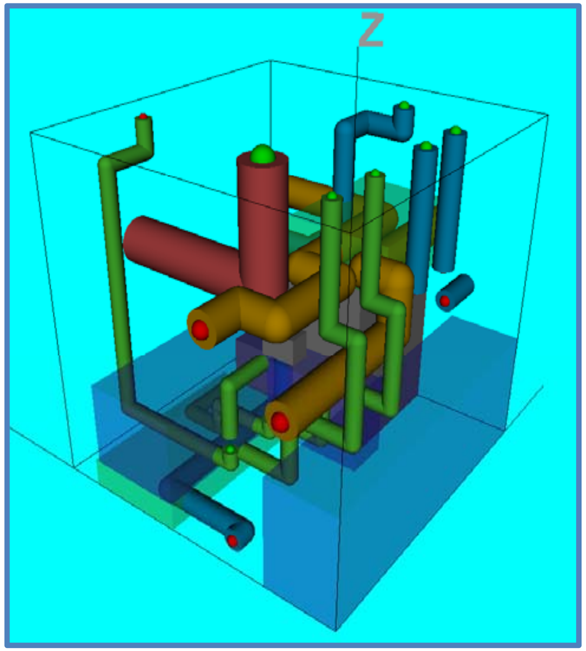
Conclusion

New automatic pipe routing system

- **Features**
  - **Minimize total length,**
  - **Minimize number of bending,**
  - **Pass through pipe-racks,**
  - **Avoid aisles,**
  - **Avoid making "Pockets"**



Conclusion

<u>New automatic pipe routing system</u>

- **Features**

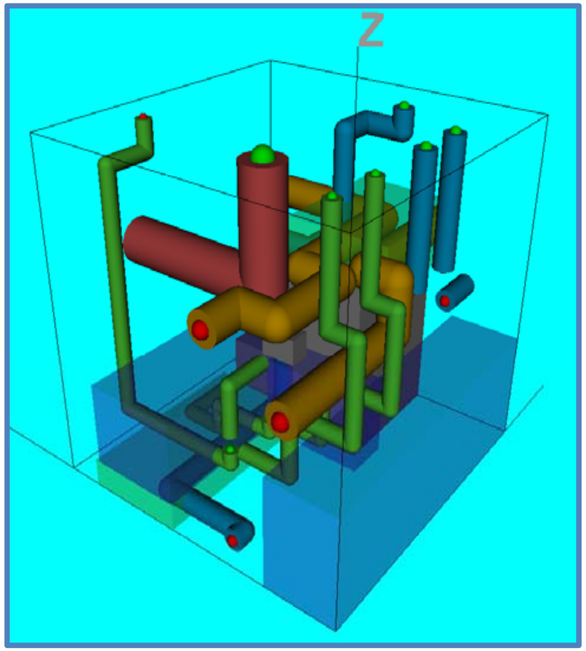
  Minimize total length,

  Minimize number of bending,

  Pass through pipe-racks,

  Avoid aisles,

  <u>Avoid making "Pockets"</u>

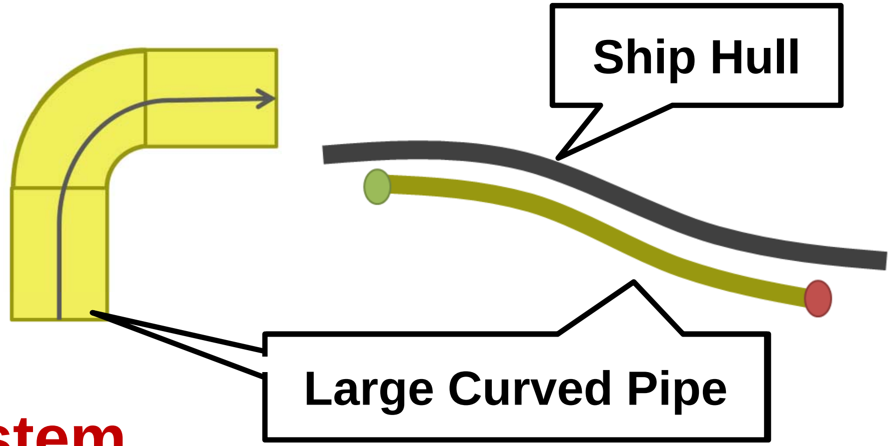


- Restriction Method (Reduce the size of graph)

- Penalty Method (Add penalties to the vertical edges)

Future Tasks

- Order of Routing
- Search Time
- More practical routes



- **Equipment Placing System**

This routing system will be opened for free at

http://sysplan.nams.kyushu-u.ac.jp/gen/index.html

Thank you!