

Automated and Connected Driving Challenges

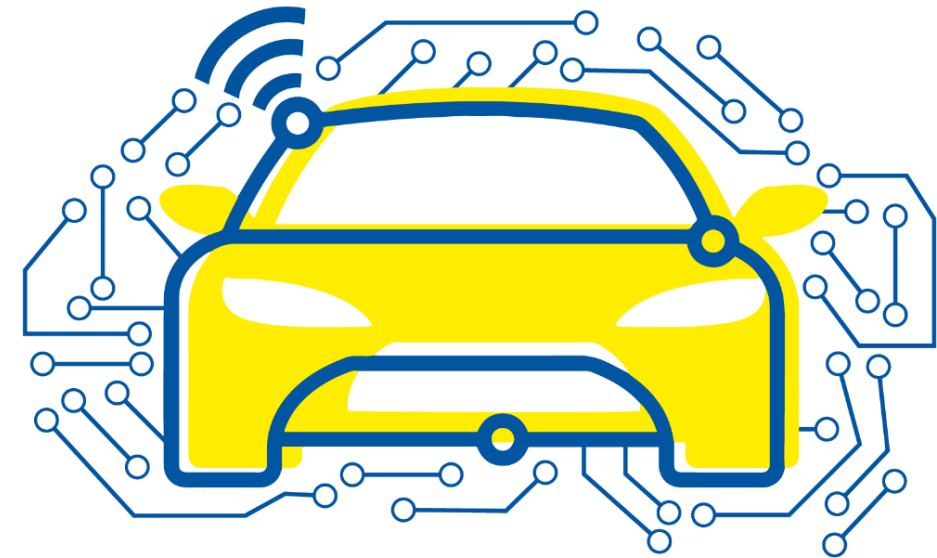
Section 4 – Vehicle Guidance

Vehicle Guidance on Navigation Level

Introduction

Bastian Lampe

Institute for Automotive Engineering





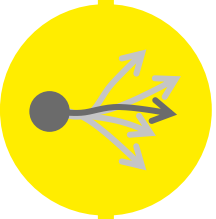
Vehicle Guidance on Navigation Level

Bellman's Principle of Optimality

- Principle of Optimality:

“An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision.”

- Dynamic programming breaks the planning problem into simpler steps at different states in time
- The optimal solution is then composed from piece wise optimal solutions
- Discretization of configuration-space necessary



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Dynamic Programming

- Almost any cost-function can be applied
 - Global optimum can be calculated efficiently
- Combinatorial problems:
- Parking applications
 - Route-Planning
 - Collision avoidance of multiple obstacles
 - Decision making

- „Curse of dimensionality“
 - Exponential increase in complexity with increasing number of states
- A priori constraints for possible maneuvers

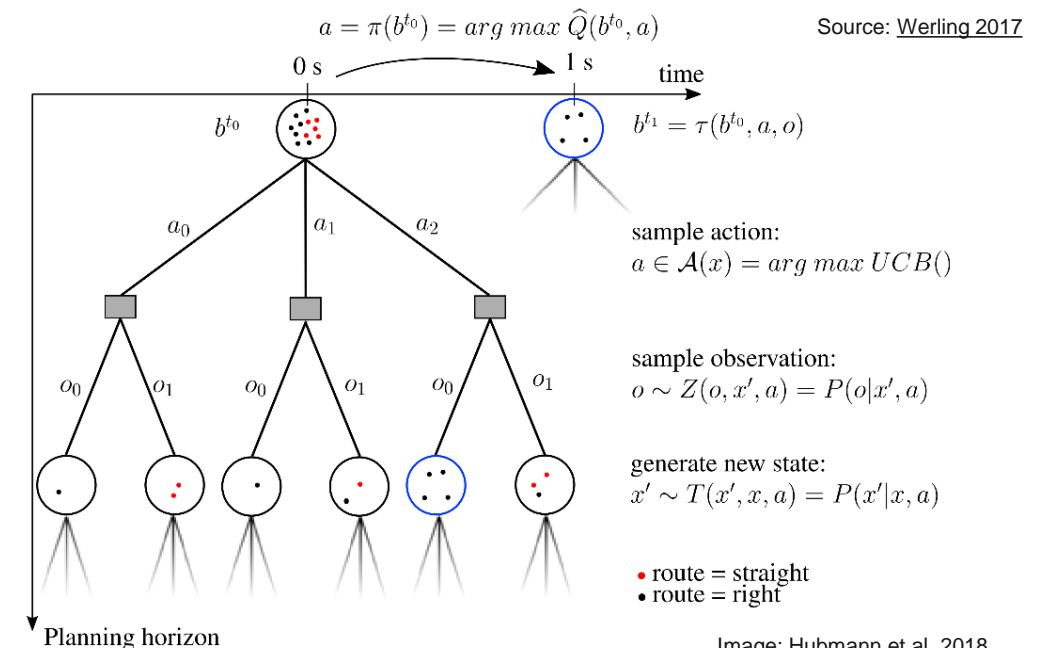
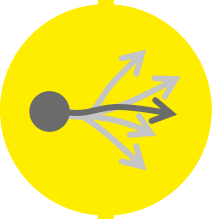


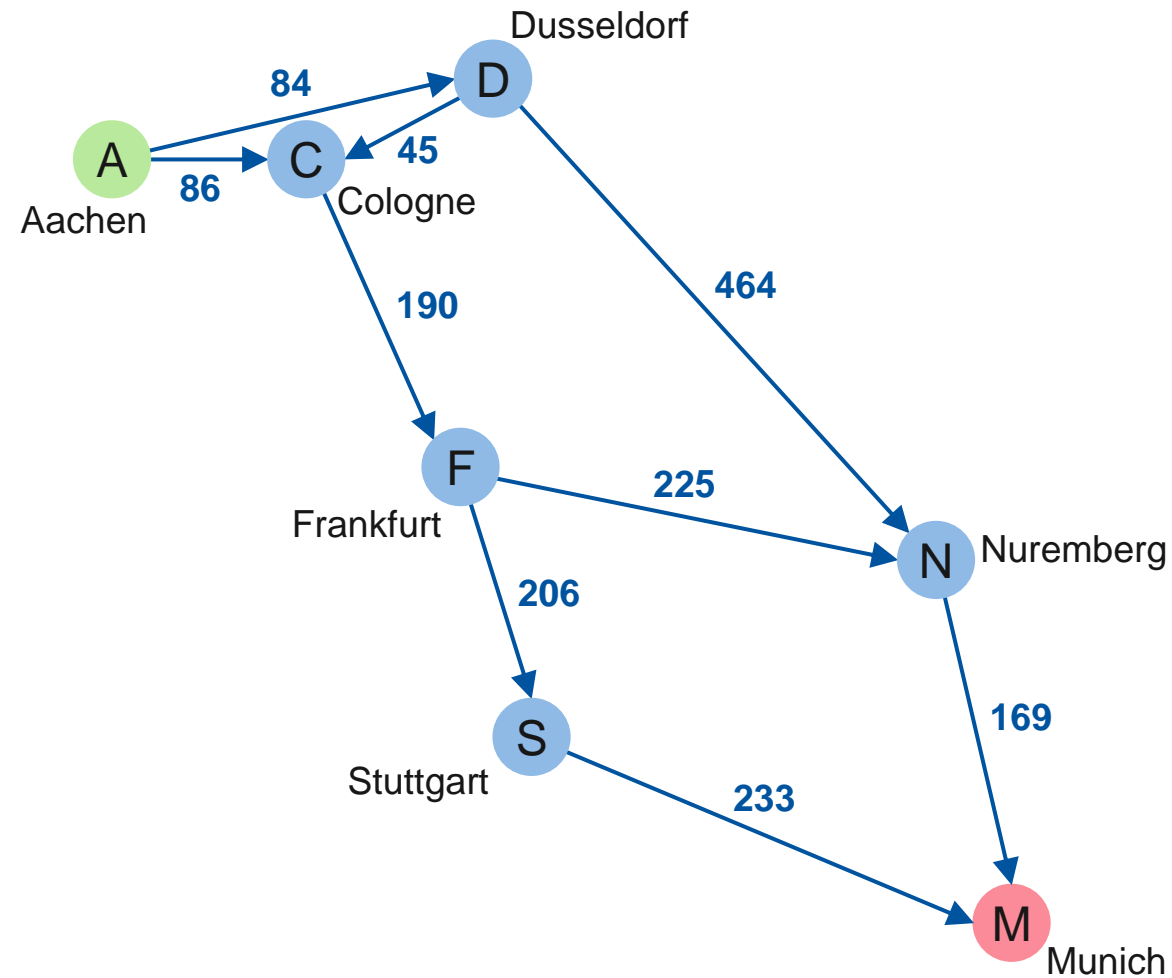
Image: Hubmann et al. 2018

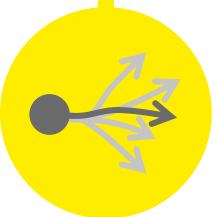
POMDP with Tree-Search



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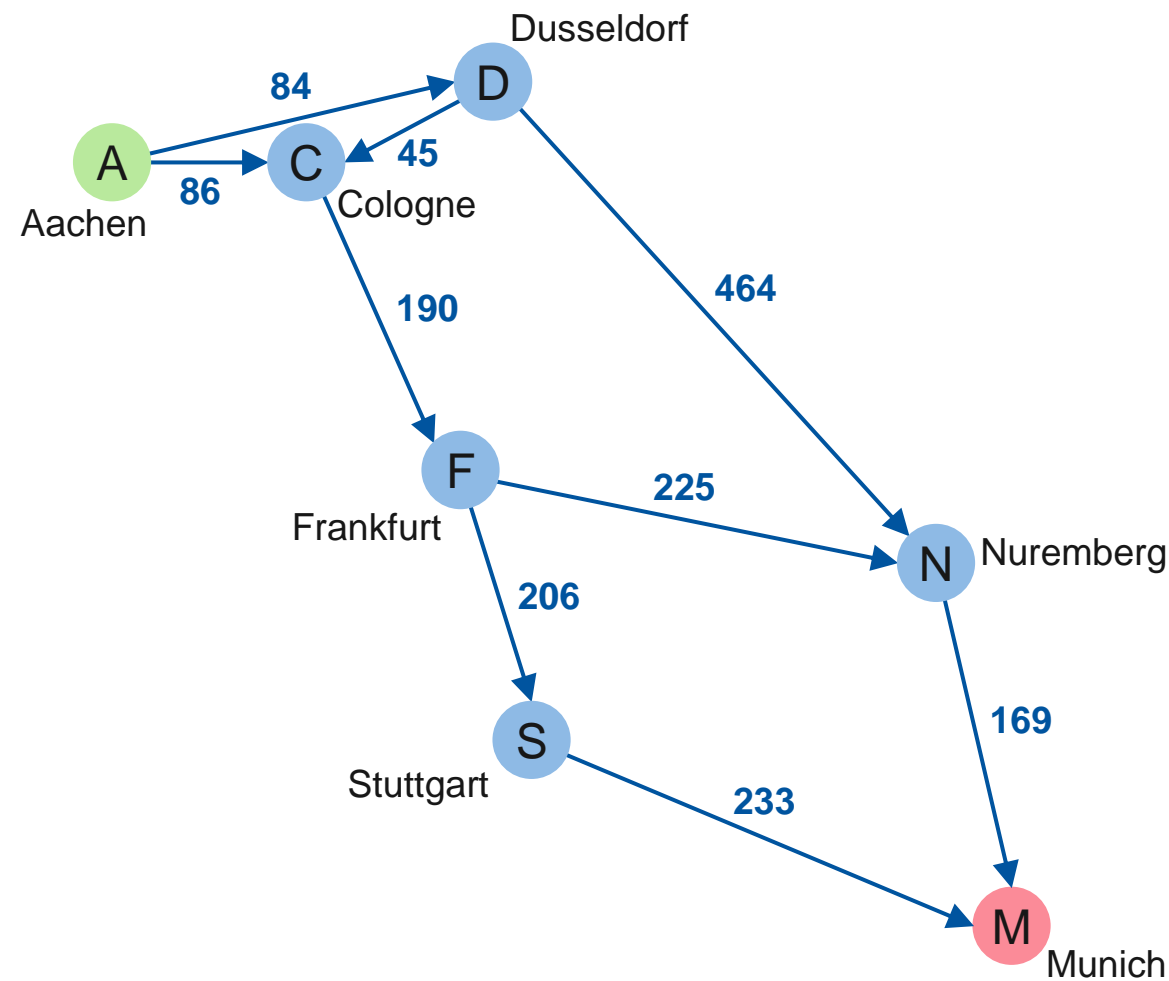
Example: Dijkstra Graph Search





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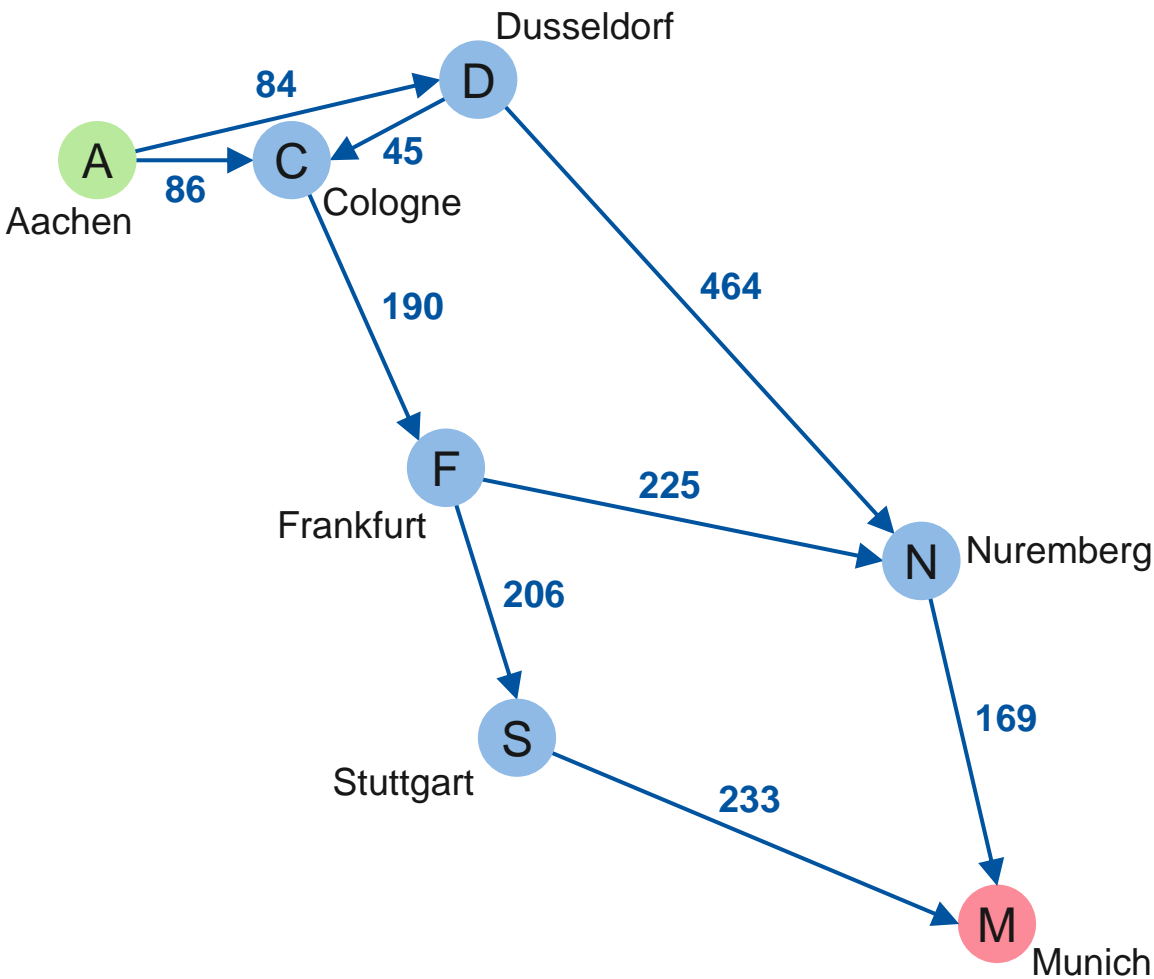
Example: Dijkstra Graph Search





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Example: Dijkstra Graph Search

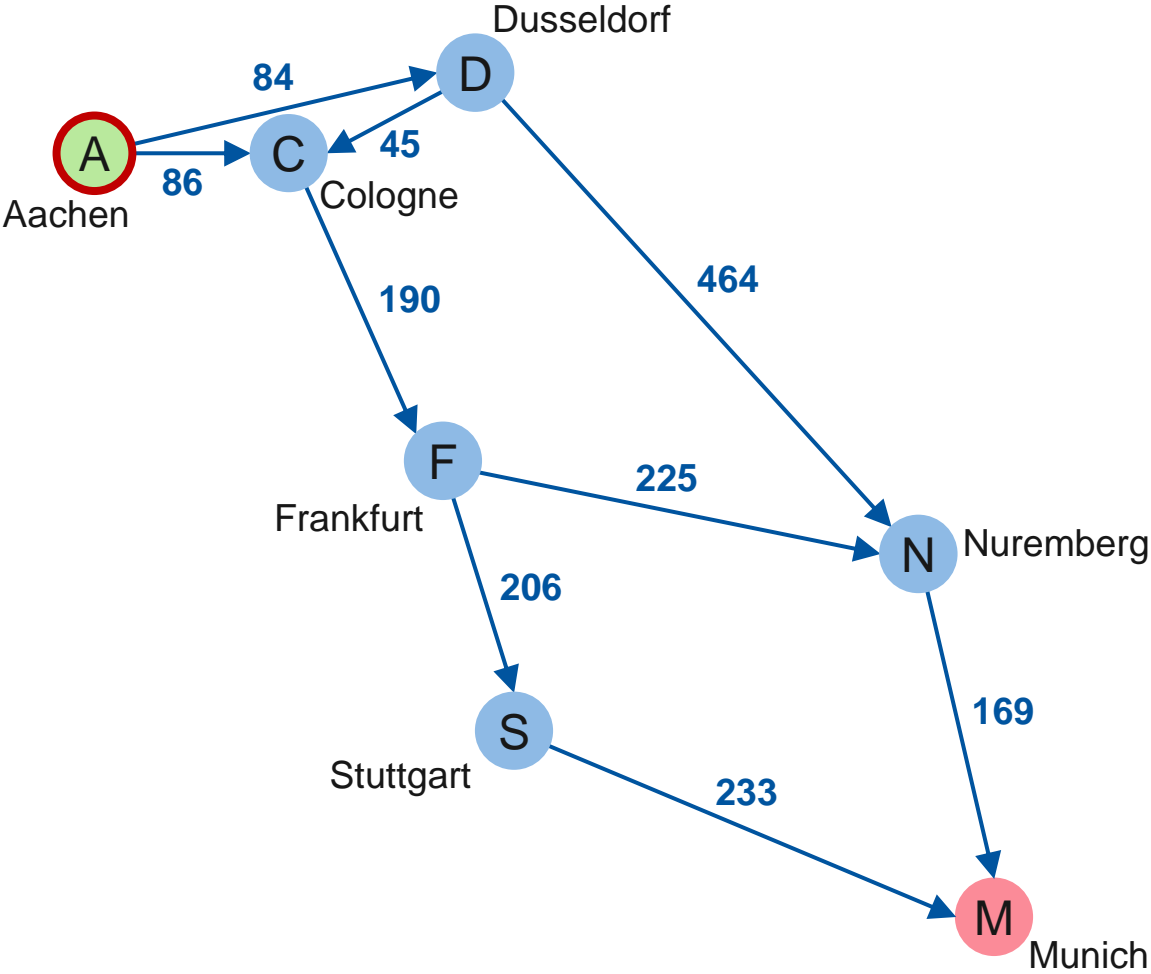


		A	C	D	F	S	N	M
0	Cost							
	Pre							
1	Cost							
	Pre							
2	Cost							
	Pre							
3	Cost							
	Pre							
4	Cost							
	Pre							
5	Cost							
	Pre							
6	Cost							
	Pre							



Vehicle Guidance on Navigation Level

Example: Dijkstra Graph Search

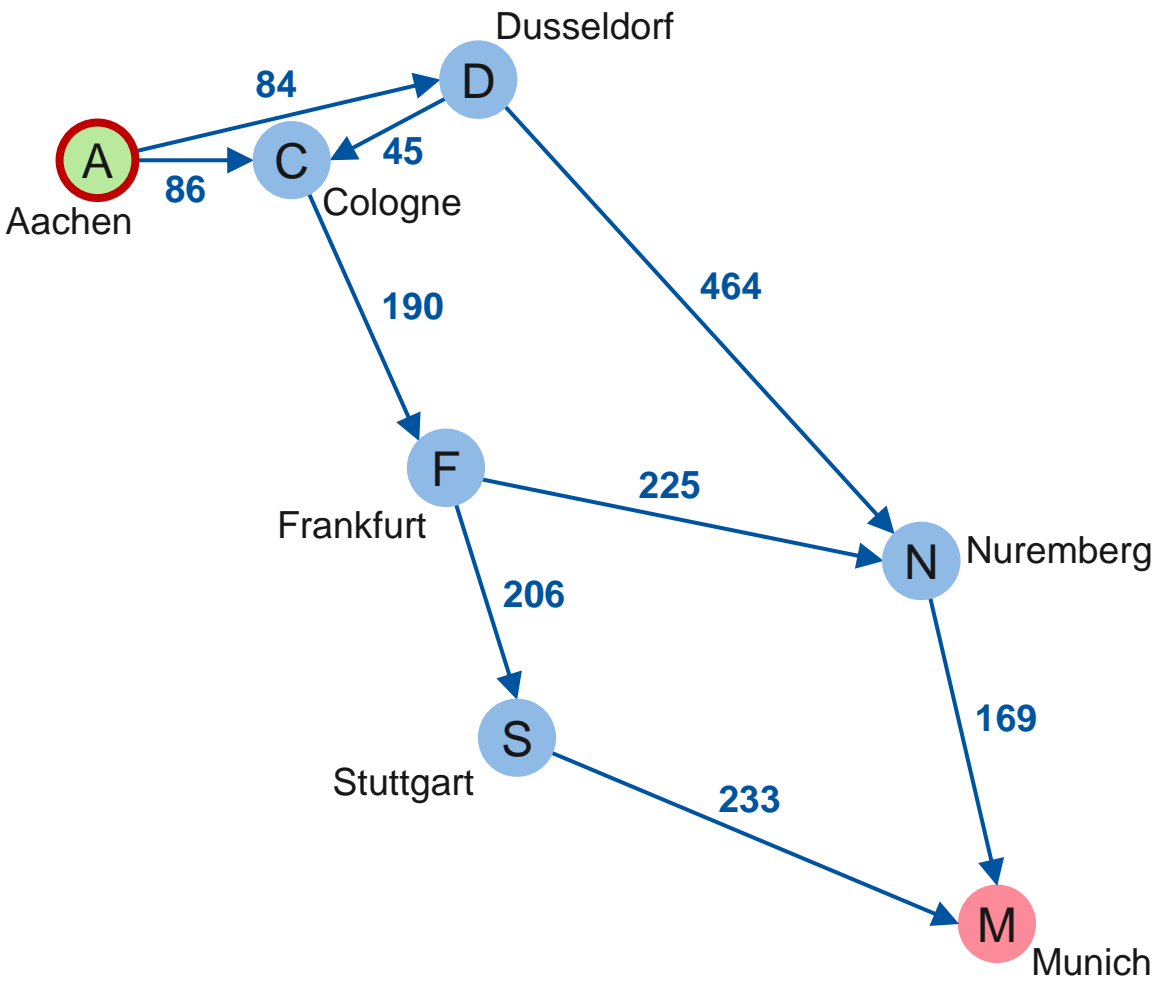


		A	C	D	F	S	N	M
0	Cost	0	∞	∞	∞	∞	∞	∞
	Pre	-						
1	Cost							
	Pre							
2	Cost							
	Pre							
3	Cost							
	Pre							
4	Cost							
	Pre							
5	Cost							
	Pre							
6	Cost							
	Pre							



Vehicle Guidance on Navigation Level

Example: Dijkstra Graph Search



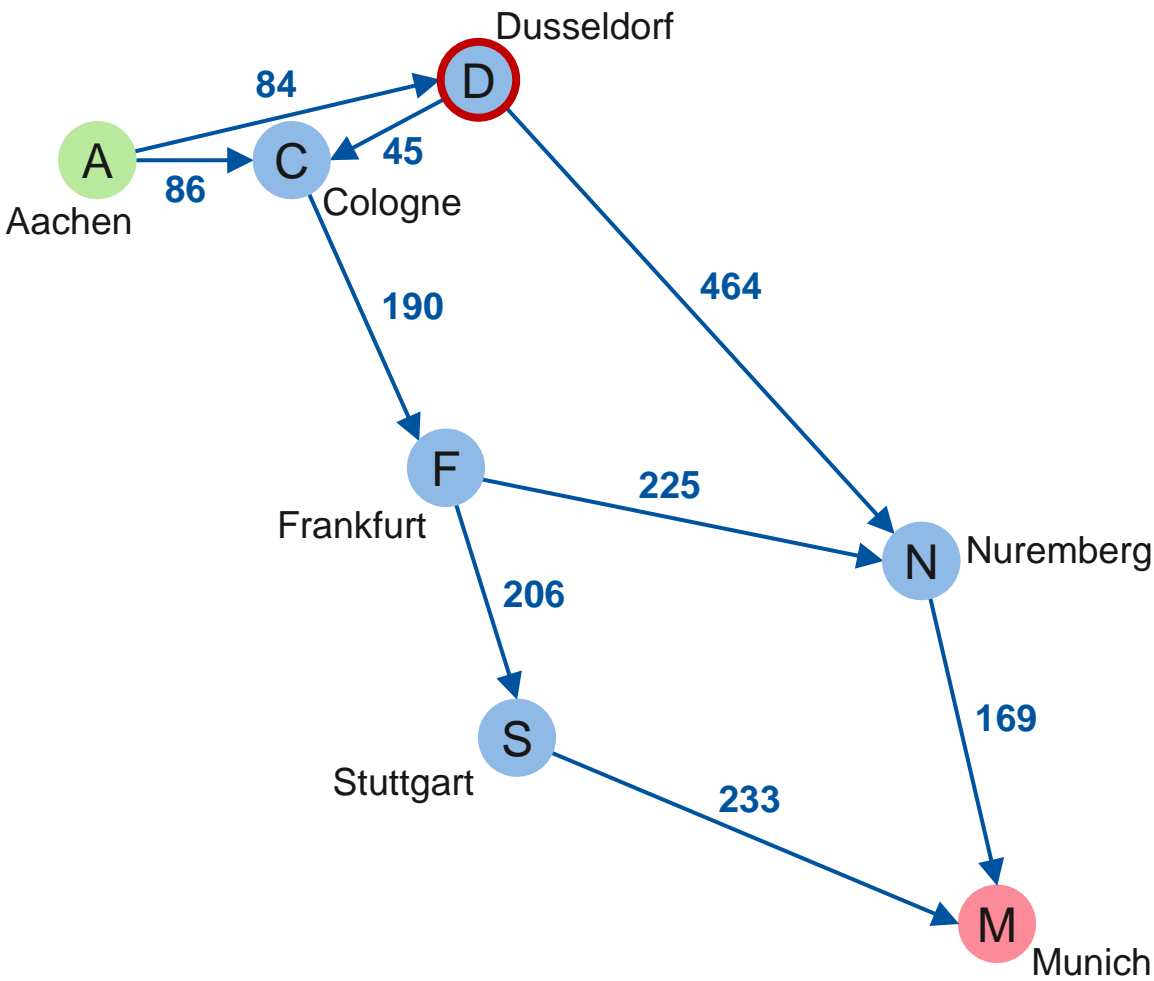
A

		A	C	D	F	S	N	M
0	Cost	0	∞	∞	∞	∞	∞	∞
	Pre	-						
1	Cost	0	86	84	∞	∞	∞	∞
	Pre	-	A	A				
2	Cost							
	Pre							
3	Cost							
	Pre							
4	Cost							
	Pre							
5	Cost							
	Pre							
6	Cost							
	Pre							

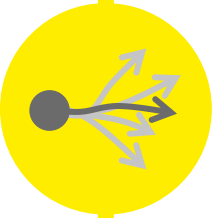


Vehicle Guidance on Navigation Level

Example: Dijkstra Graph Search

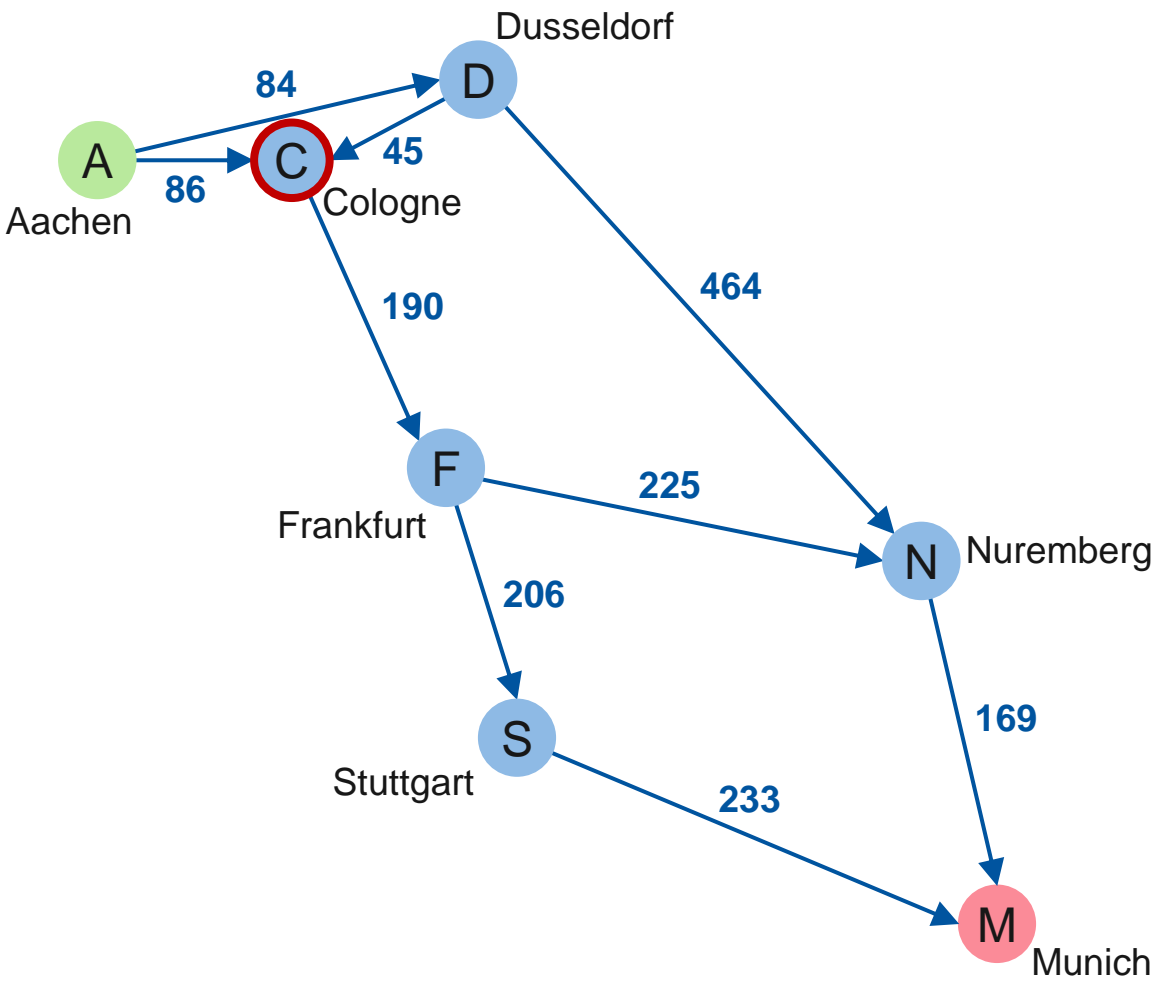


		A	C	D	F	S	N	M
0	Cost	0	∞	∞	∞	∞	∞	∞
	Pre	-						
1	Cost	0	86	84	∞	∞	∞	∞
	Pre	-	A	A				
2	Cost	0	86	84	∞	∞	548	∞
	Pre	-	A	A			D	
3	Cost							
	Pre							
4	Cost							
	Pre							
5	Cost							
	Pre							
6	Cost							
	Pre							

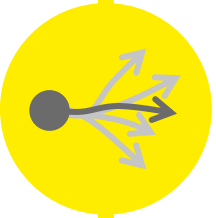


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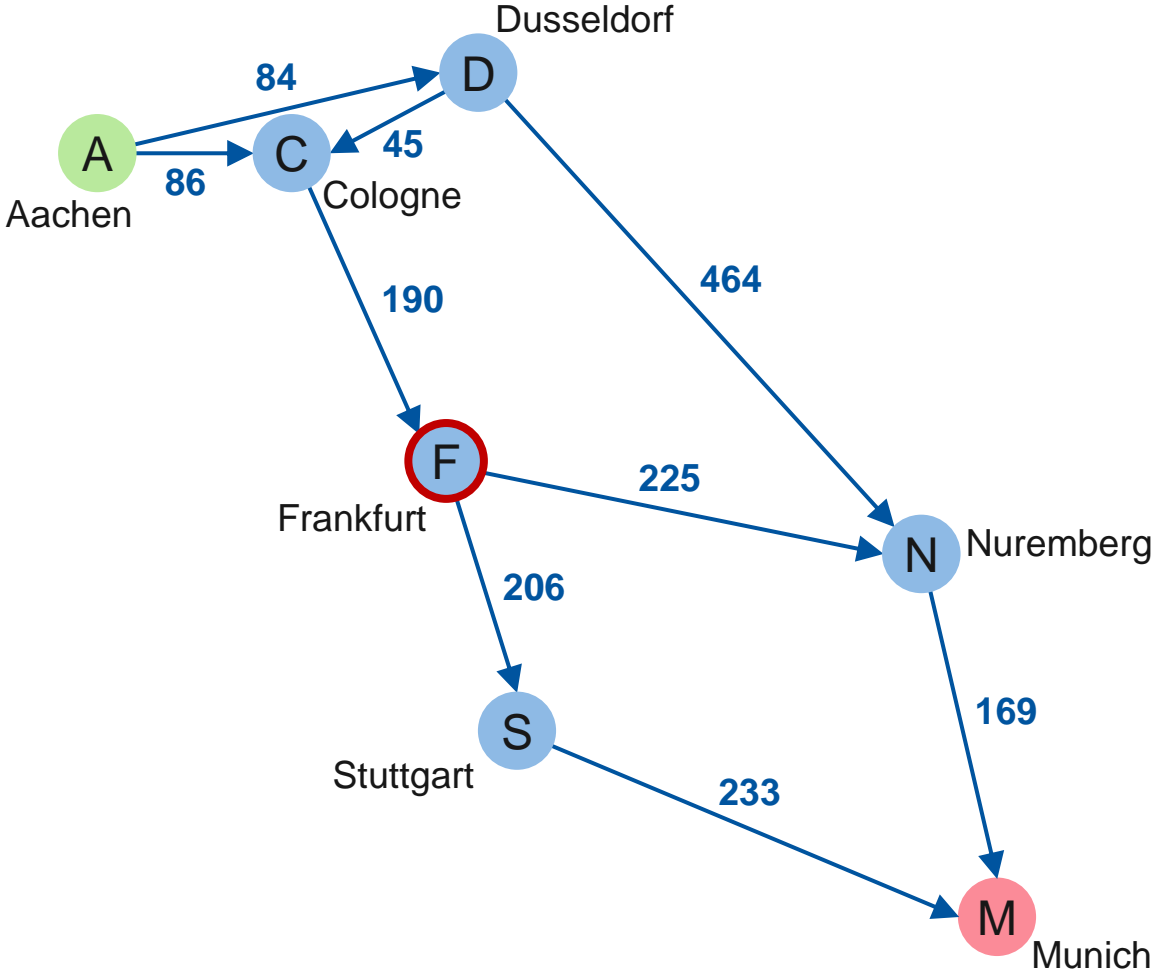


		A	C	D	F	S	N	M
0	Cost	0	∞	∞	∞	∞	∞	∞
	Pre	-						
1	Cost	0	86	84	∞	∞	∞	∞
	Pre	-	A	A				
2	Cost	0	86	84	∞	∞	548	∞
	Pre	-	A	A			D	
3	Cost	0	86	84	276	∞	548	∞
	Pre	-	A	A	C		D	
4	Cost							
	Pre							
5	Cost							
	Pre							
6	Cost							
	Pre							



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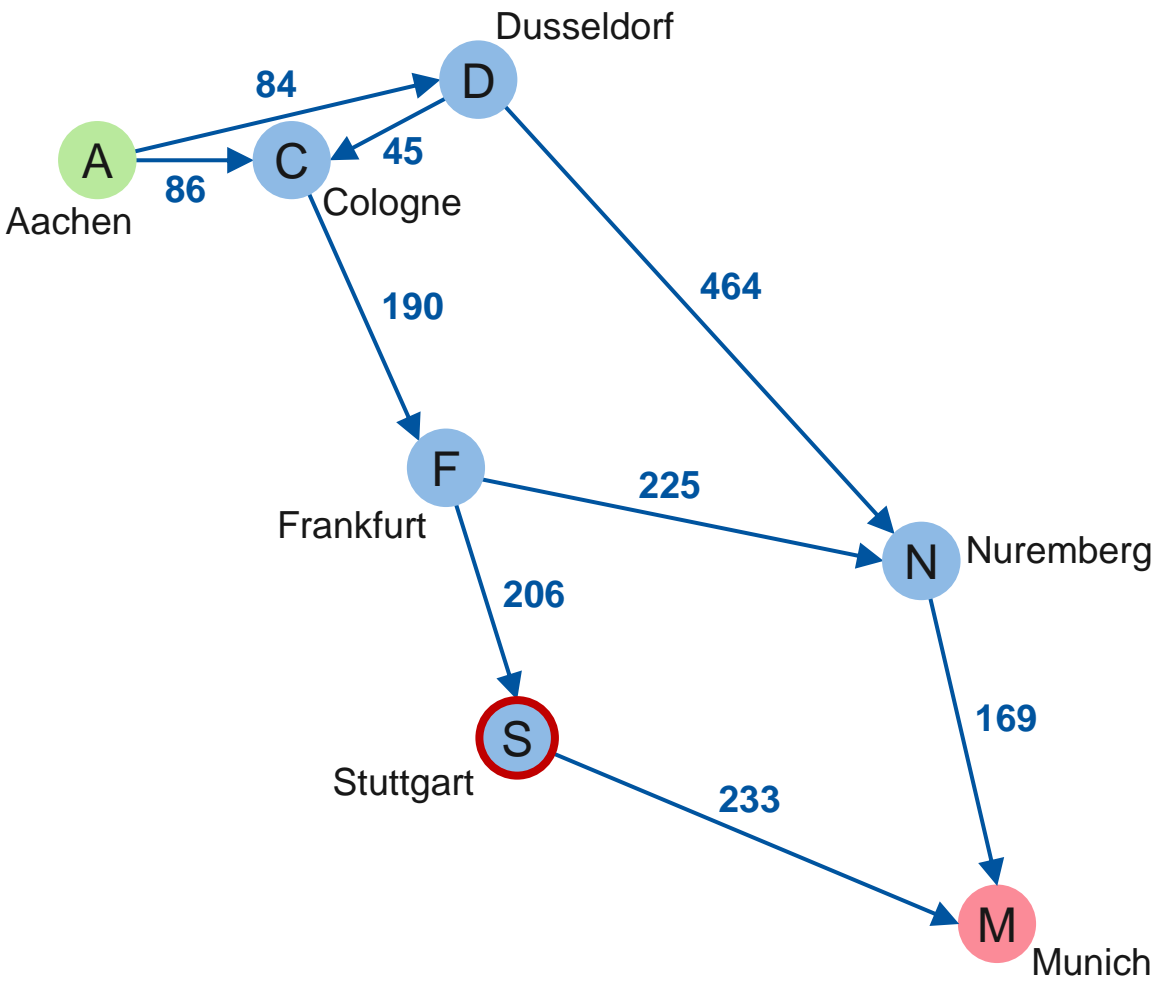


		A	C	D	F	S	N	M
0	Cost	0	∞	∞	∞	∞	∞	∞
	Pre	-						
1	Cost	0	86	84	∞	∞	∞	∞
	Pre	-	A	A				
2	Cost	0	86	84	∞	∞	548	∞
	Pre	-	A	A			D	
3	Cost	0	86	84	276	∞	548	∞
	Pre	-	A	A	C		D	
4	Cost	0	86	84	276	482	501	∞
	Pre	-	A	A	C	F	F	
5	Cost							
	Pre							
6	Cost							
	Pre							

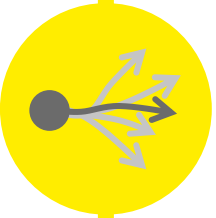


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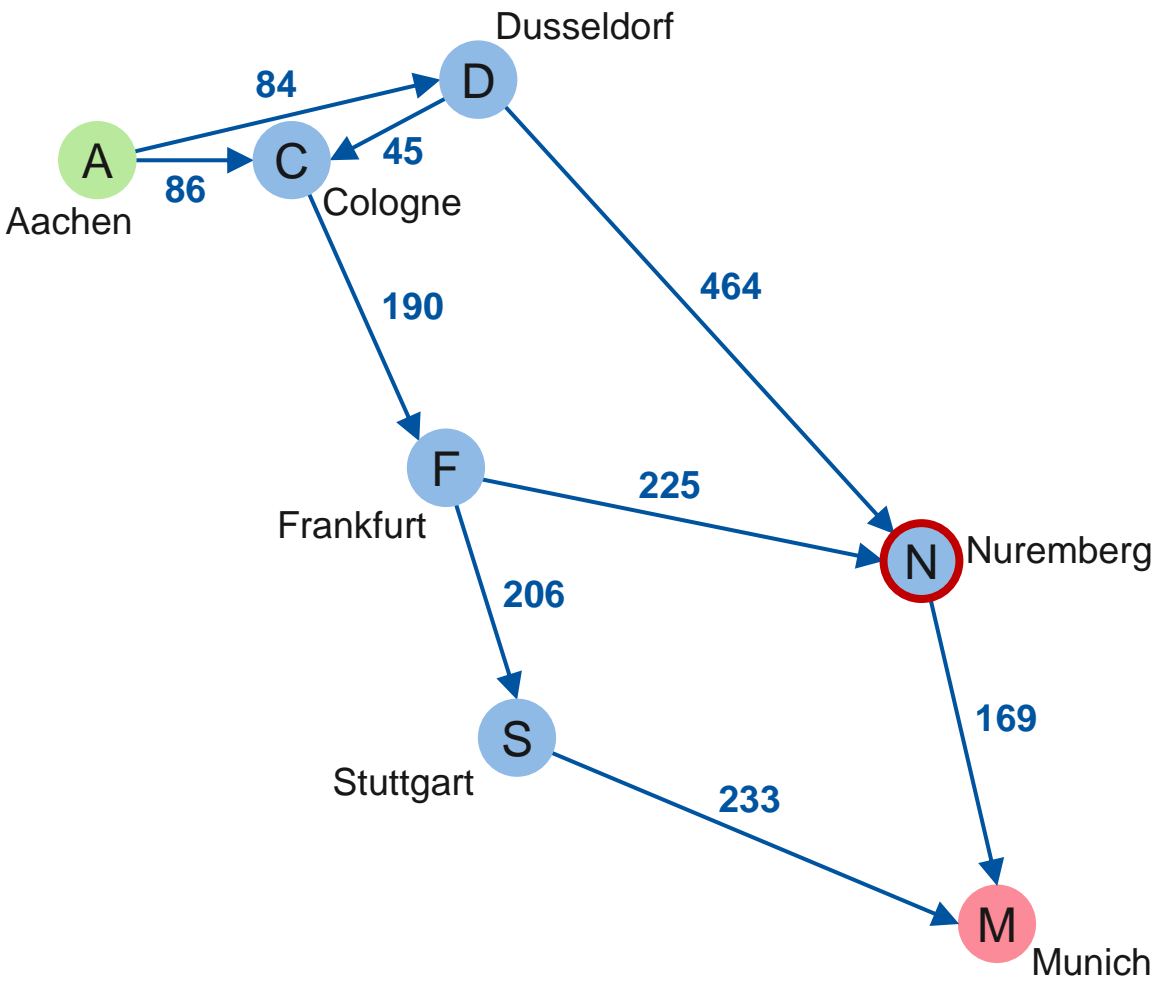


		A	C	D	F	S	N	M
0	Cost	0	∞	∞	∞	∞	∞	∞
	Pre	-						
1	Cost	0	86	84	∞	∞	∞	∞
	Pre	-	A	A				
2	Cost	0	86	84	∞	∞	548	∞
	Pre	-	A	A			D	
3	Cost	0	86	84	276	∞	548	∞
	Pre	-	A	A	C		D	
4	Cost	0	86	84	276	482	501	∞
	Pre	-	A	A	C	F	F	
5	Cost	0	86	84	276	482	501	715
	Pre	-	A	A	C	F	F	S
6	Cost							
	Pre							

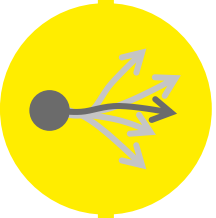


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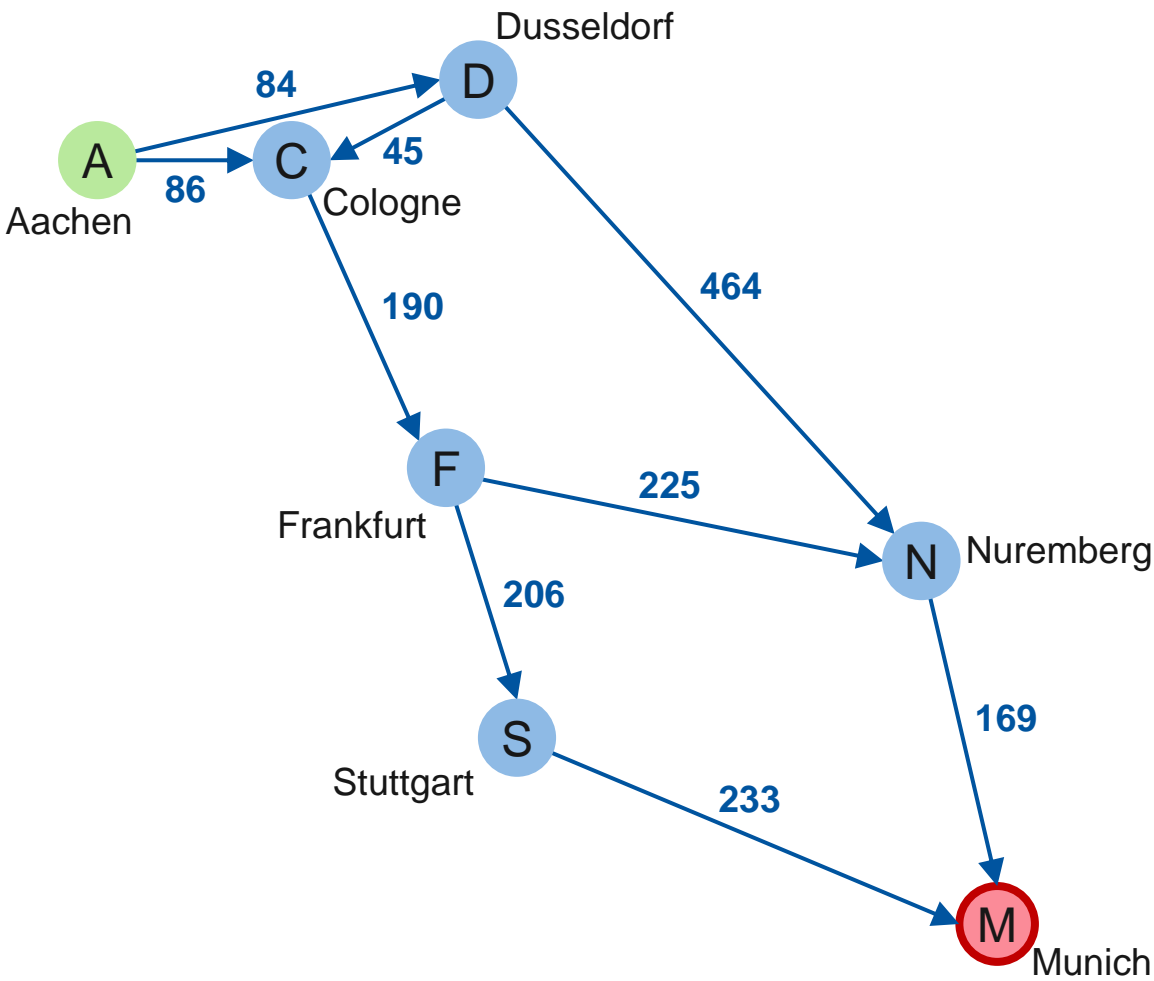


		A	C	D	F	S	N	M
0	Cost	0	∞	∞	∞	∞	∞	∞
	Pre	-						
1	Cost	0	86	84	∞	∞	∞	∞
	Pre	-	A	A				
2	Cost	0	86	84	∞	∞	548	∞
	Pre	-	A	A			D	
3	Cost	0	86	84	276	∞	548	∞
	Pre	-	A	A	C		D	
4	Cost	0	86	84	276	482	501	∞
	Pre	-	A	A	C	F	F	
5	Cost	0	86	84	276	482	501	715
	Pre	-	A	A	C	F	F	S
6	Cost	0	86	84	276	482	501	670
	Pre	-	A	A	C	F	F	N

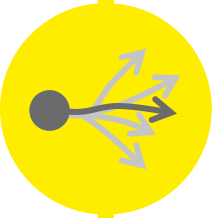


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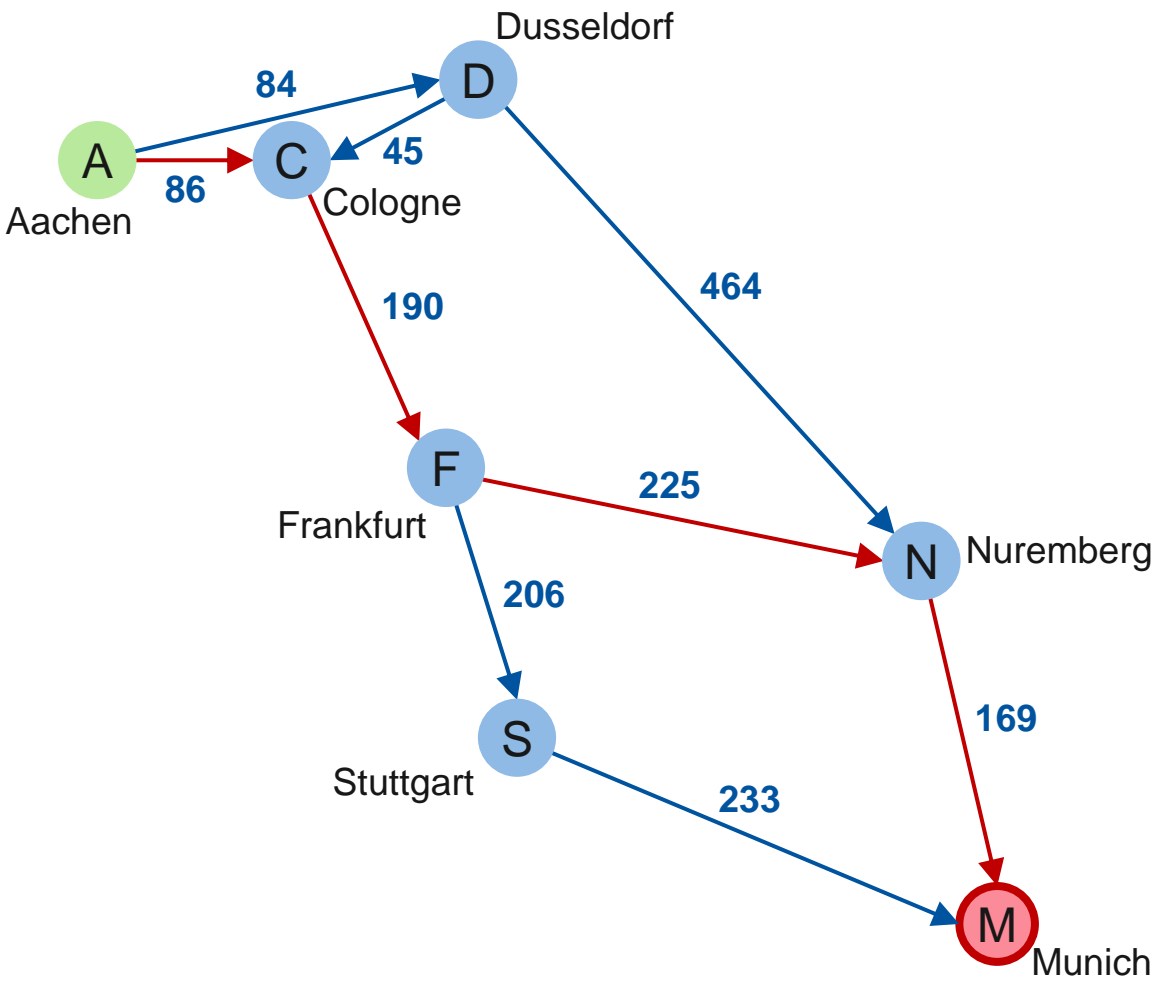


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	Pre	-						
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	Pre	-	A	A				
2	Cost	0	86	84	∞	∞	548	∞
	Pre	-	A	A			D	
3	Cost	0	86	84	276	∞	548	∞
	Pre	-	A	A	C		D	
4	Cost	0	86	84	276	482	501	∞
	Pre	-	A	A	C	F	F	
5	Cost	0	86	84	276	482	501	715
	Pre	-	A	A	C	F	F	S
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	Pre	-	A	A	C	F	F	N



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	Pre	-	A	A	C	F	F	
5	Cost	0	86	84	276	482	501	715
	Pre	-	A	A	C	F	F	S
6	Cost	0	86	84	276	482	501	670
	Pre	-	A	A	C	F	F	N