Algorithms

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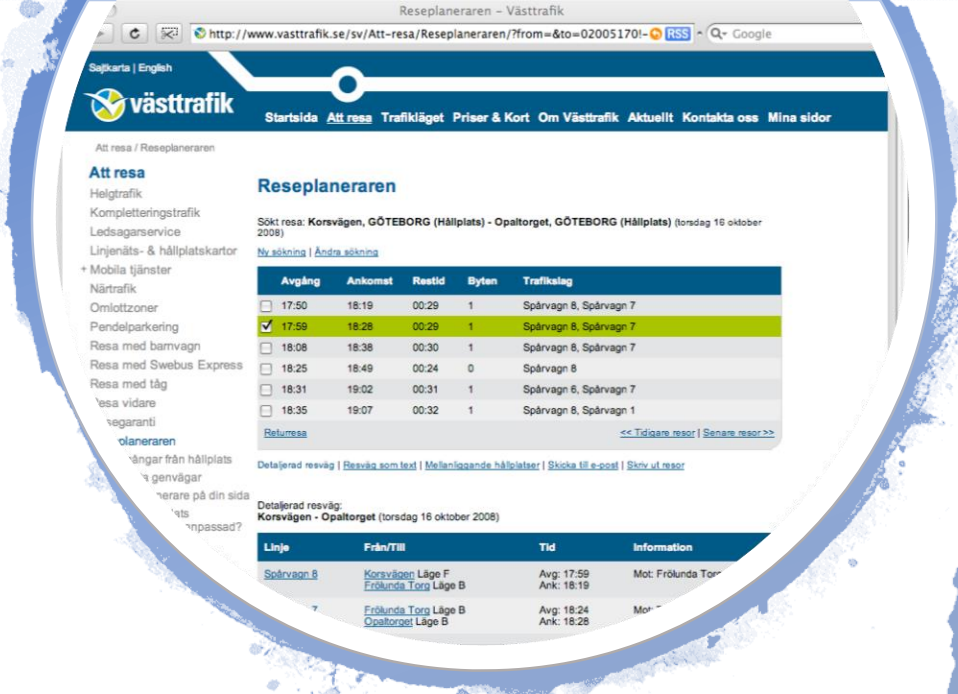
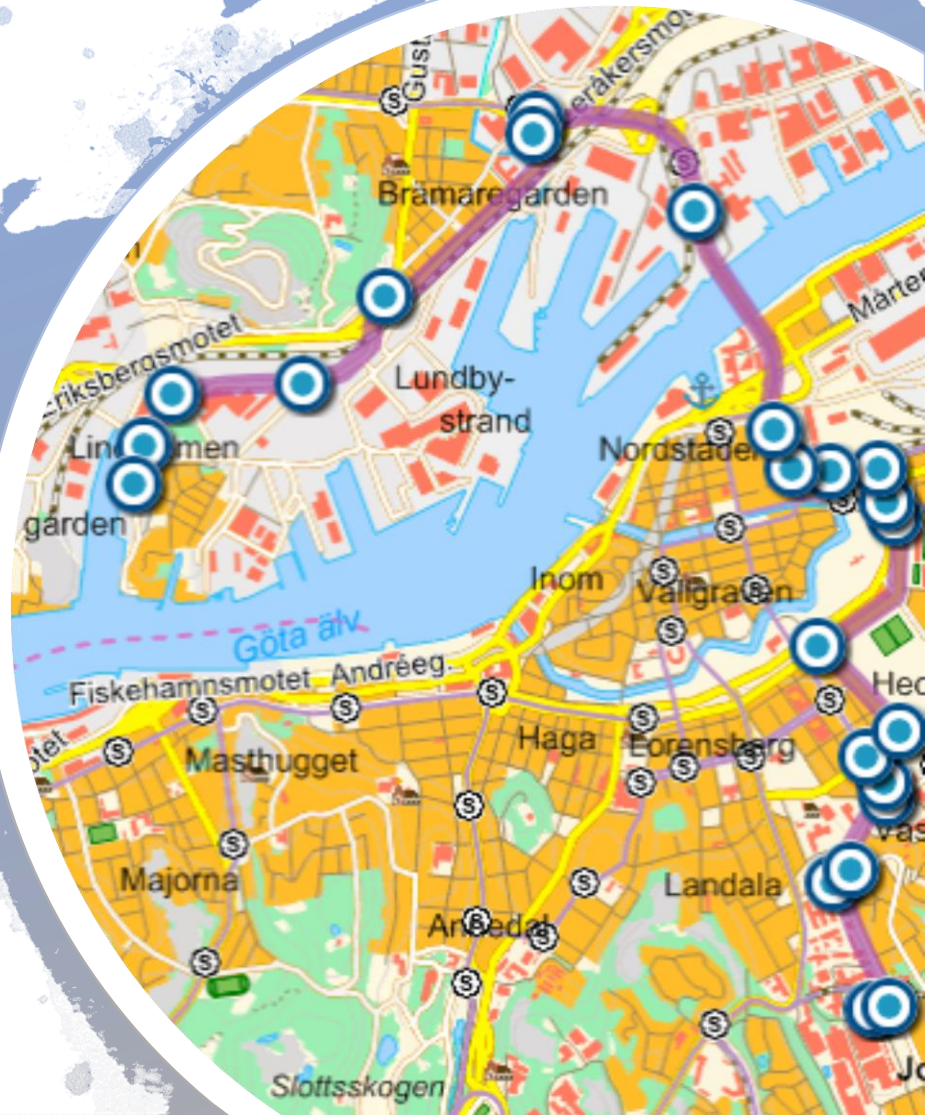
2019-11-06


Algorithm
Sorting
Searching
Maximum
Search
points
path
ICPC
DFS
BFS
Shortest
Matching
Longest
Subsequence
Exponentiation
First
Optimal
convex
vertex
graph
line
Hungarian
GameTheory
Modular
Flow
Matrix
Method
Distance

Used an Algorithm Today?

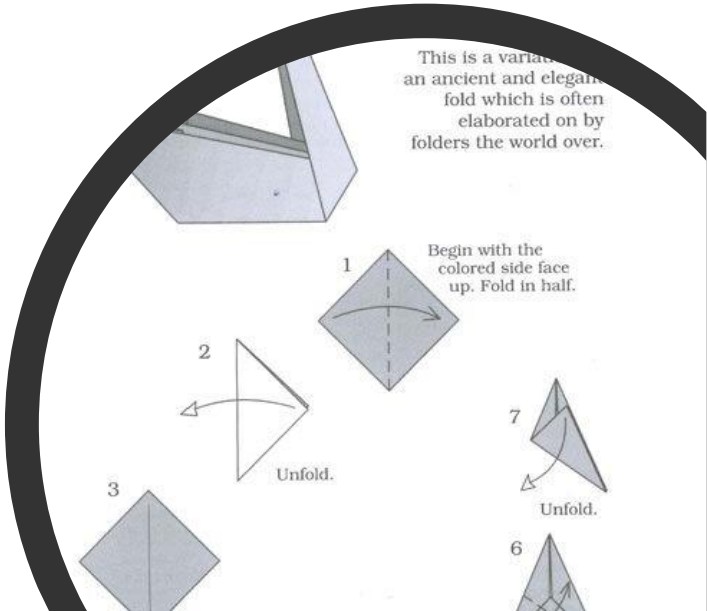




Used an Algorithm Today?

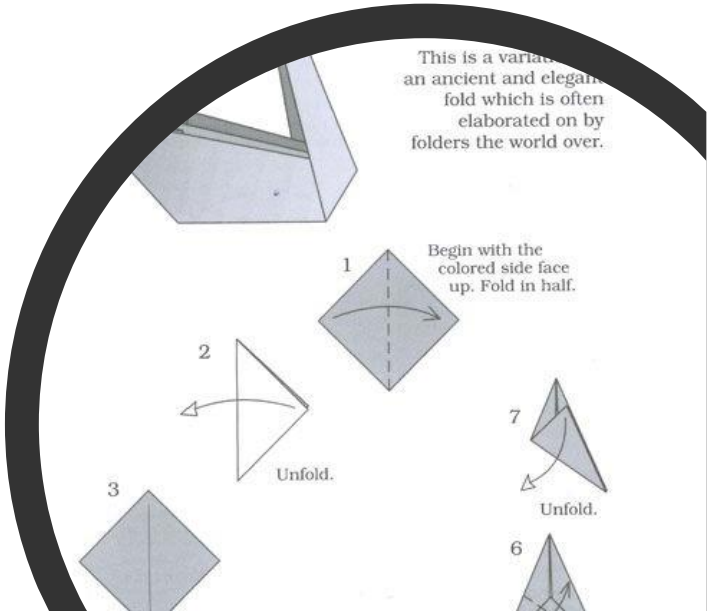
Used an algorithm today?

- Bake a cake
- Google translate
- Internet banking
- Google search
- Origami Swan



Used an algorithm today?

FTFTALILL-AVAV
--FTAL-LLAAV--



What is an Algorithm?

A set of steps that defines how a task is performed.

An algorithm is an ordered set of unambiguous, executable steps that defines a terminating process.

Brookshear

What is an Algorithm?

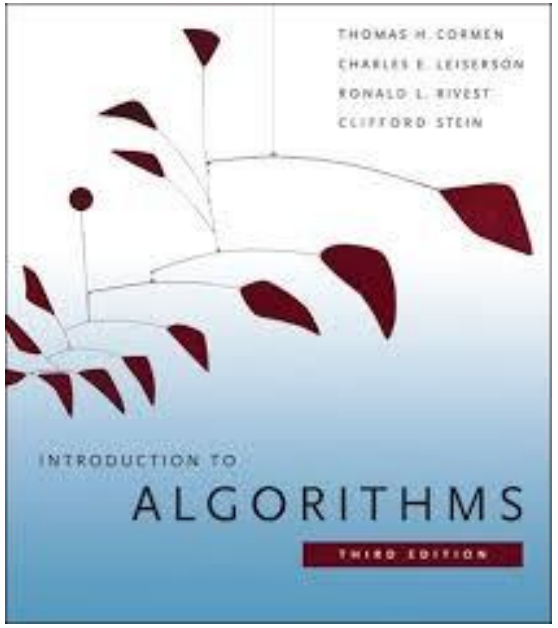
An Algorithm is a well-defined computational procedure that takes some value, or a set of values, as input and

produces some value, or set of values as output.

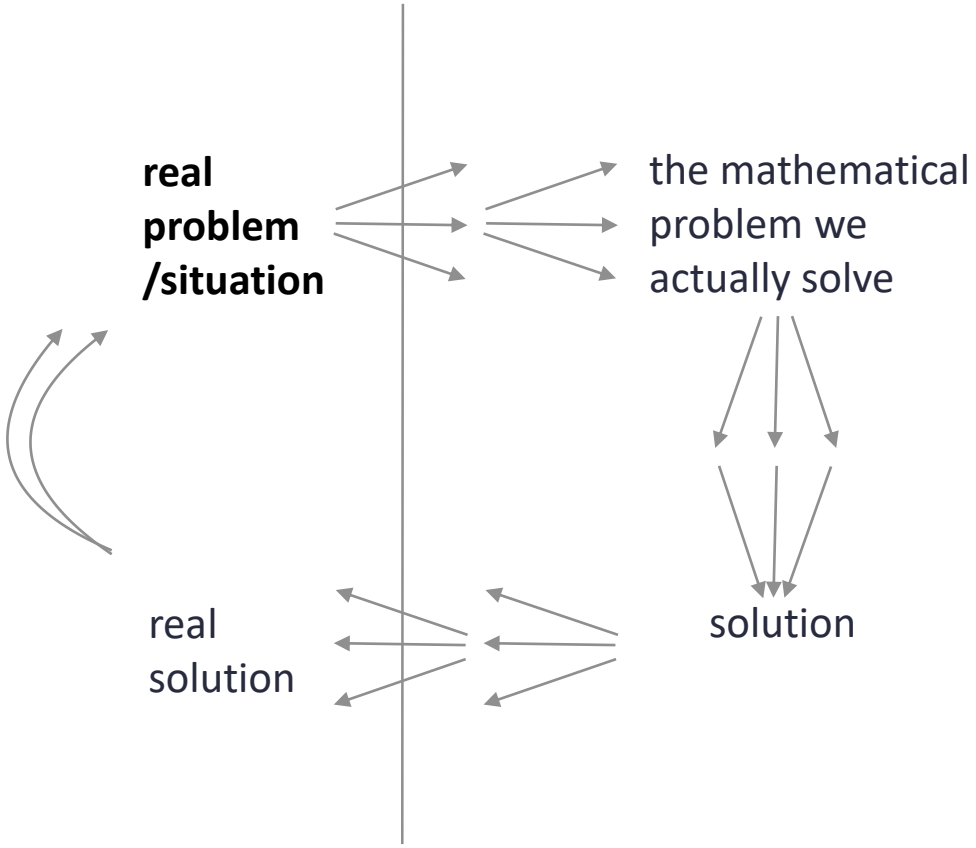
An algorithm is thus a sequence of computational steps

that transform input into output.

- More formal definition uses Turing machines



Algorithms in relation to modelling and problem solving



An iterative and creative design process!

First Known Algorithm?

- Greatest common divisor (GCD) algorithm by Euclid ca 300 B.C.

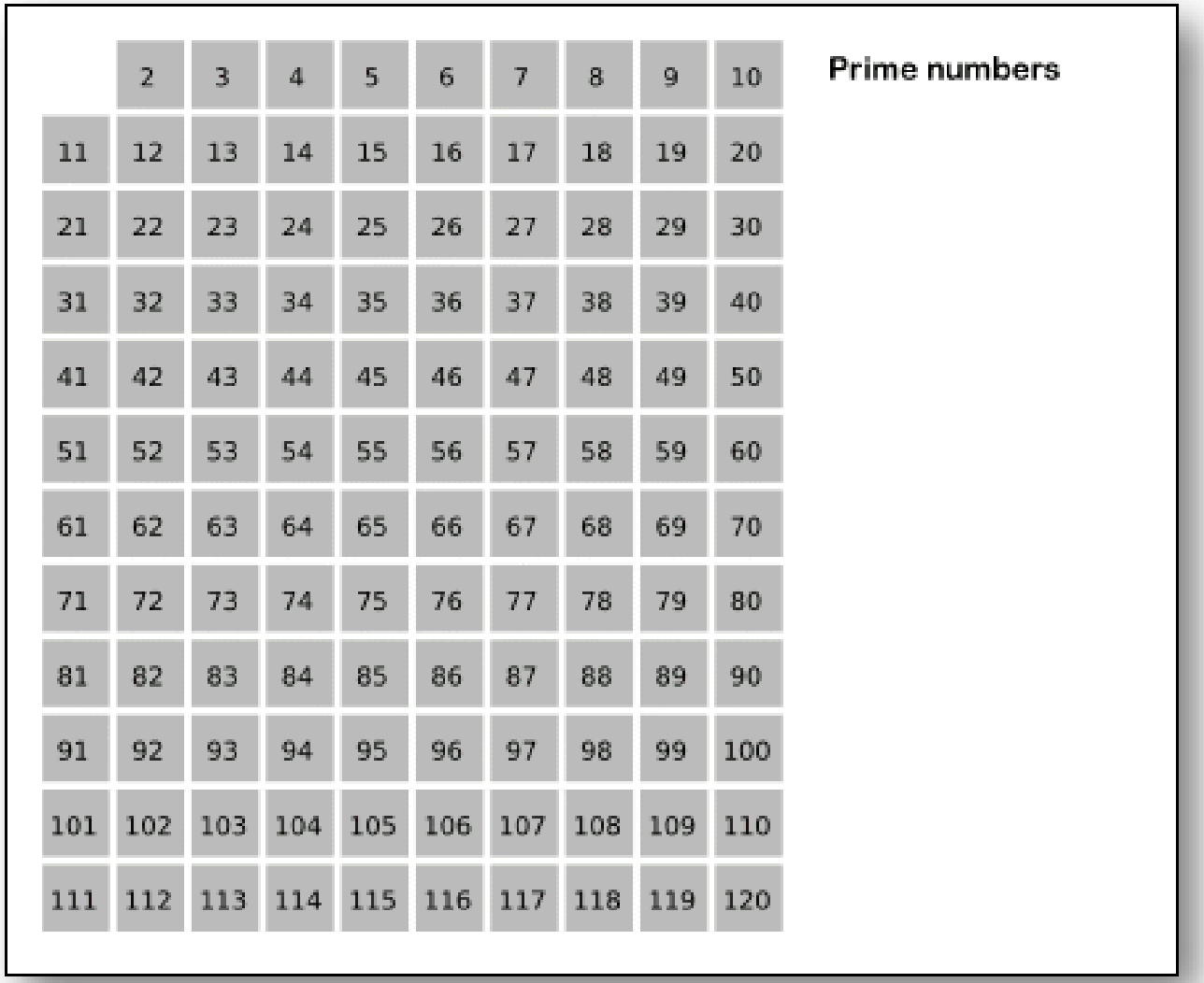
Euclid´s Elements

- Prime numbers: Sieve of Eratosthenes, ca 200 B.C.

Animations: (sorting and prime numbers)

https://www.youtube.com/watch?v=ZZuD6iUe3Pc
https://en.wikipedia.org/wiki/Sieve_of_Eratosthenes

Sieve of Eratosthenes



	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120

Some History

700 BC — Thales of Milet
600 BC — Pythagoras
500 BC
400 BC
300 BC — Euklid, Archimedes
200 BC — Eratosthenes
100 BC
Year Zero
100 AD — H. of Alexandria
200 AD — K. Ptolemaios
300 AD — D. of Alexandria
400 AD — Hypatia
500 AD — Decade System
200 AD — Aryabhata
600 AD — Brahmagupa
700 AD — al-Khowarizmi
800 AD
900 AD
1000 AD — Ibn al-Haitham, al-Biruni
1700 AD
1800 AD — First Computer P.
1900 AD — Ada Lovelace, Church Turing Th., Church, Turing, Neumann, First Computer, Hopper, Nash, Public Key Crypt., Ellis, Artificial Intelligence, Mc Carthy, Elgamal, Web Search Engine, Page, Brin
2000 AD

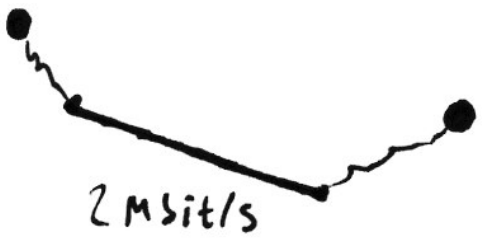
HOME

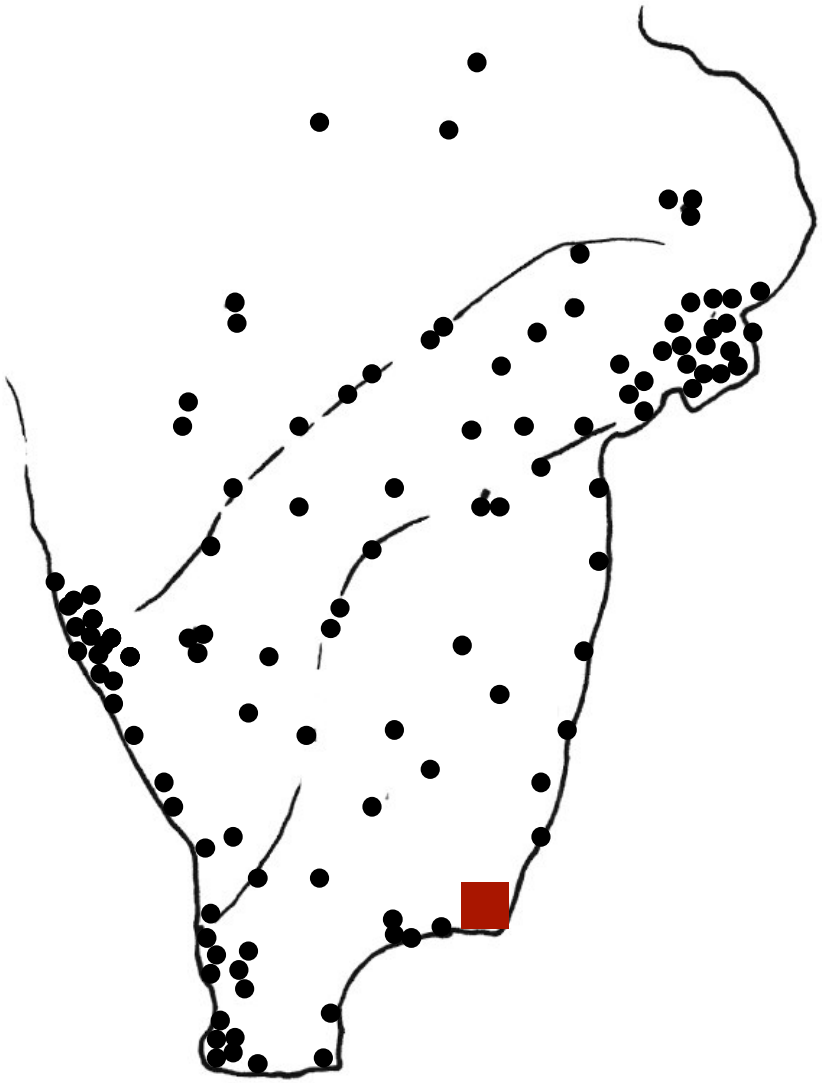
http://cs-exhibitions.uni-klu.ac.at/index.php?id=193

Telephone operator problem (real applied problem)

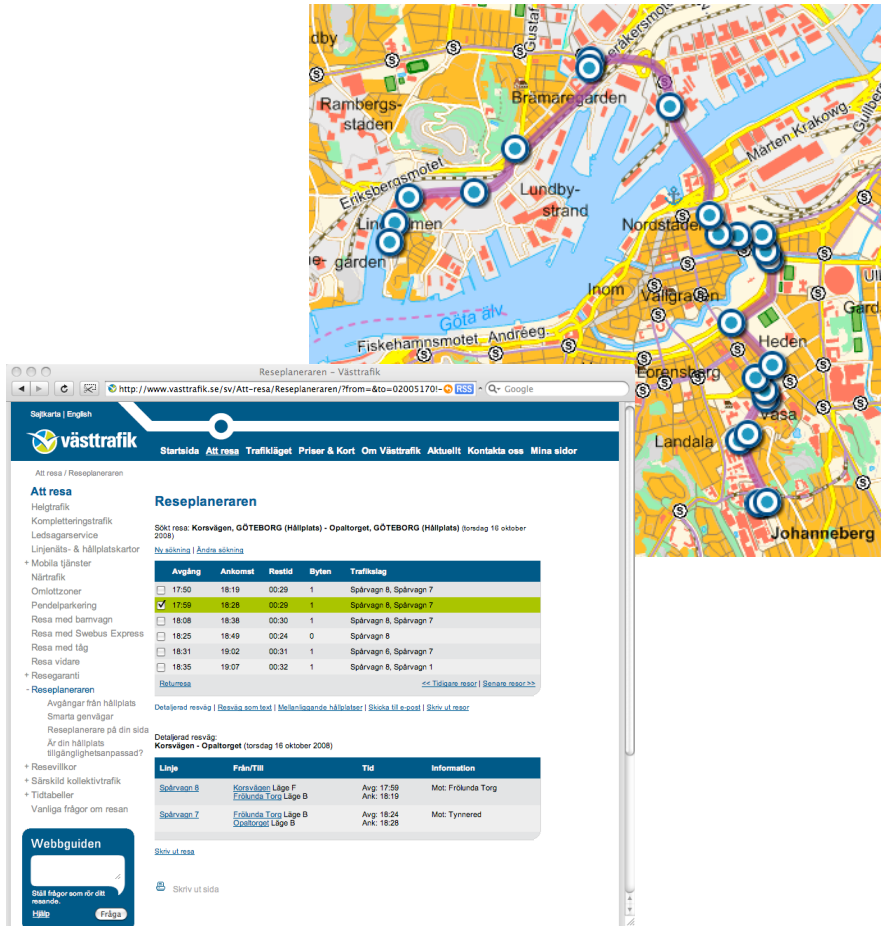
A Swedish mobile phone operator needs to connect all base station to its main switch.

How can we best rent communication lines from the national fixed network?



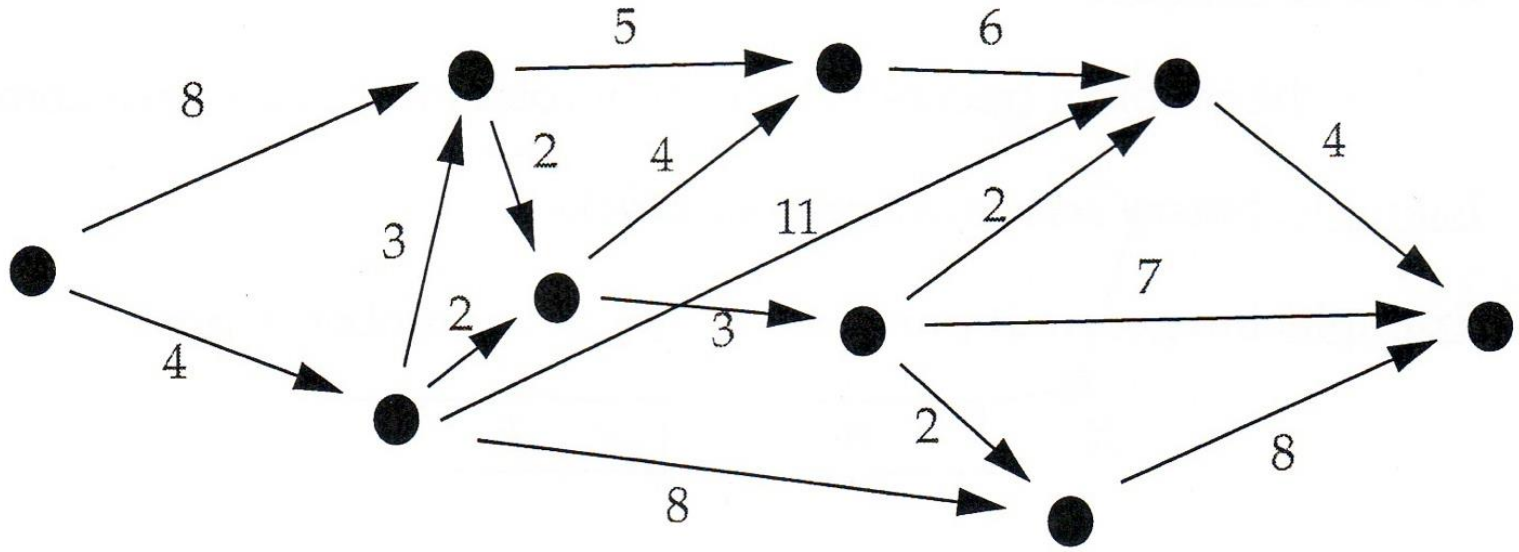


The Shortest Path Problem



How solve?

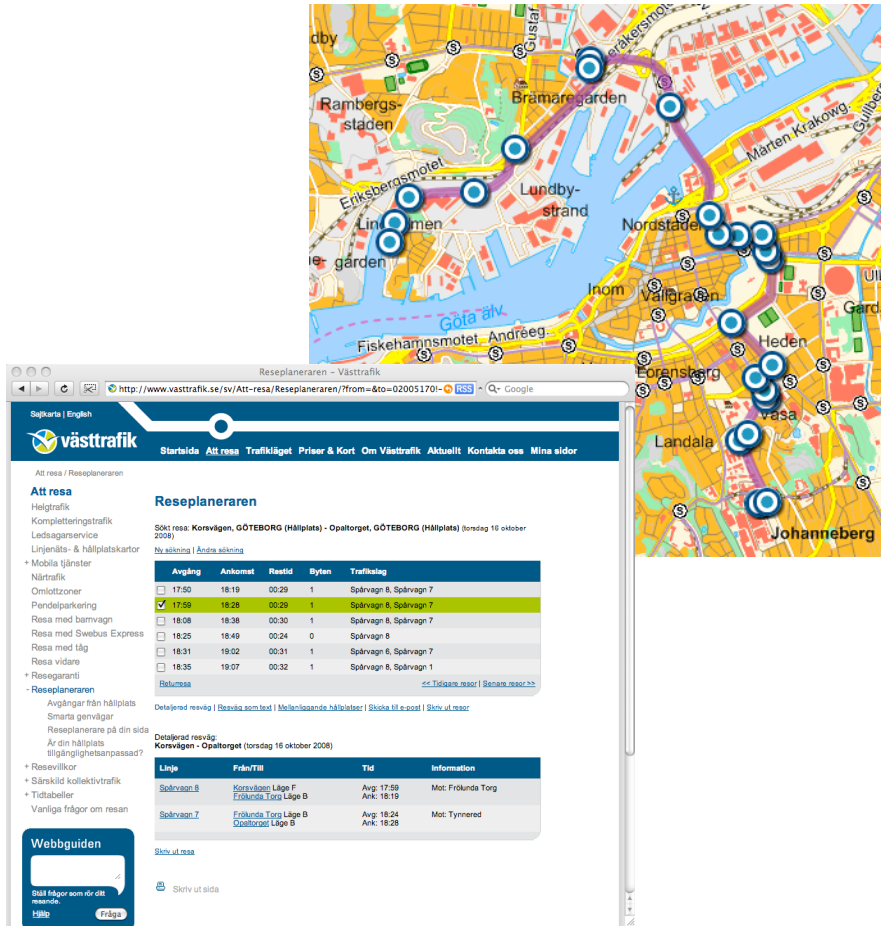
Solving the directed shortest path problem with dynamic programming



Traverse nodes from left to right and mark with distance from origin. Dijkstra´s algorithm 1956 .

Circumvents the combinatorial explosion!
(not possible for all kinds of problems)

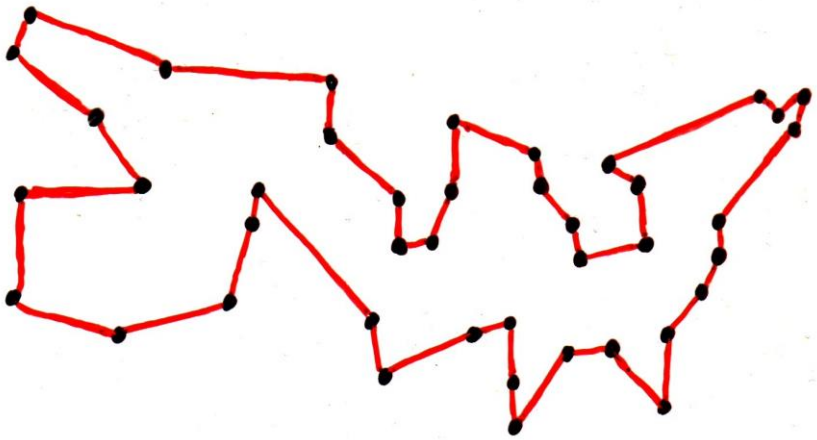
The Shortest Path Problem



polynomial growth

n	c n^2
10	0,001 s
20	0,004 s
30	0,009 s
40	0,016 s
50	0,025 s
60	0,036 s

The Travelling Salesperson Problem

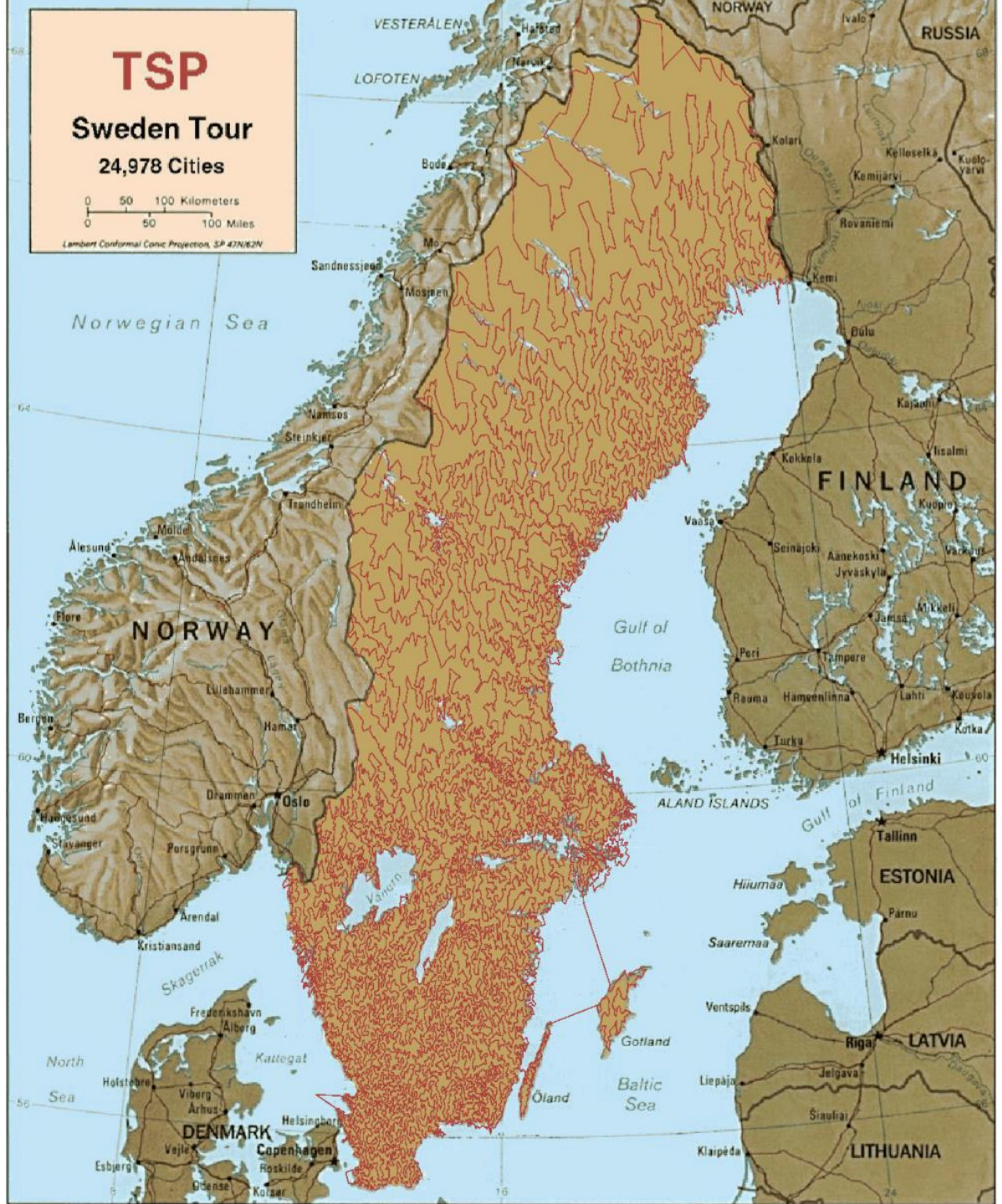


no known polynomial algorithm!

exponential growth

n	c 2^n
10	0,001 s
20	1 s
30	18 min
40	13 days
50	36 years
60	36600 years

Why is TSP difficult? Reference and examples:
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=11&ved=2ahUKEwiL6OP_iNjlAhURzaQKHcCeCHEQFjAKegQIAhAC&url=https%3A%2F%2Fpdfs.semanticscholar.org%2F7487%2Fea033b1729fb7695841673ece0e4782fdb88.pdf&usg=AOvVaw3914Eqq0wxHhc6vbw-c-gK


TSP
Sweden Tour
24,978 Cities
0 50 100 Kilometers
0 50 100 Miles
Lambert Conformal Conic Projection, SP 47N/62N
VESTERÅLEN
LOFOTEN
NORWAY
RUSSIA
Norwegian Sea
FINLAND
NORWAY
Gulf of Bothnia
ALAND ISLANDS
Gulf of Finland
ESTONIA
LATVIA
LITHUANIA
DENMARK
Skagerrak
Kattegat
North Sea
Baltic Sea
Gotland
Öland
Hiiumaa
Saaremaa
Bodø
Sandnessjøen
Mosjøen
Namsos
Steinkjer
Trondheim
Molde
Ålesund
Andalsnes
Florø
Bergen
Lillehammer
Hamar
Drammen
Oslo
Haugesund
Stavanger
Porsgrunn
Arendal
Kristiansand
Frederikshavn
Ålborg
Holstebro
Viborg
Århus
Helsingborg
Esbjerg
Vejle
Copenhagen
Roskilde
Odense
Korsør
Kolari
Kelloselkä
Kuolo-yarvi
Kemijärvi
Rovaniemi
Kemi
Oulu
Kajaani
Iisalmi
Kokkola
Vaasa
Seinäjoki
Äänekoski
Jyväskylä
Mikkeli
Jämsä
Pori
Tampere
Rauma
Hämeenlinna
Lahti
Kouvola
Kotka
Turku
Helsinki
Tallinn
Pärnu
Ventspils
Riga
Jelgava
Liepāja
Šiauliai
Klaipėda


Graphic Pairing Construction
Data Plan Rule APC Report Options Help
15:25
Window 01/11 02/11 03/11 04/11 05/11 06/11 07/11 08/11 09/11 10/11 11/11 12/11 13/11 14/11
01/11 02/11 03/11 04/11
1|12 0/0/0/0/0/1/2 FRA LIN LIN FRA
1|1 0/0/0/0/0/1/2 MUC MUC
1|12345 0/0/0/0/0/1/2 FRA HAM HAM HAM HAM ATH ATH IST
1|123456 0/0/0/0/0/1/2 FRA DUS DUS DUS DUS DUS DUS
1|123456 0/0/0/0/0/1/2 FRA HAJ HAJ HAJ HAJ HAJ HAJ
1|12 0/0/0/0/0/1/2 FRA SVO SVO FRA
1|12356 0/0/0/0/0/1/2 FRA GVA GVA BRU BRU NAP
1|12 0/0/0/0/0/1/2 MUC BUD BUD MUC
1|12345 0/0/0/0/0/1/2 FRA IST IST ATH ATH IST IST ATH
1|12 0/0/0/0/0/1/2 FRA GVA GVA FRA
1|12 0/0/0/0/0/1/2 FRA CDG CDG FRA
1|123 0/0/0/0/0/1/2 FRA BRU BRU BRU BRU FRA
1|123456 0/0/0/0/0/1/2 FRA HAM HAM HAM HAM HAM HAM
1|1 0/0/0/0/0/1/2 FRA FRA
1|123 0/0/0/0/0/1/2 FRA ATH ATH LIN LIN FRA
1|1 0/0/0/0/0/1/2 FRA FRA
1|123 0/0/0/0/0/1/2 FRA HAJ HAJ GVA GVA FRA
1|1234 0/0/0/0/0/1/2 FRA DUS DUS DUS SVO SVO FRA
1|123456 0/0/0/0/0/1/2 FRA STR STR STR STR STR STR
1|123456 0/0/0/0/0/1/2 FRA DUS DUS DUS DUS DUS DUS
1|1 0/0/0/0/0/1/2 FRA FRA
1|1 0/0/0/0/0/1/2 FRA FRA
1|1 0/0/0/0/0/1/2 FRA FRA
1|1 0/0/0/0/0/1/2 FRA FRA
1|123 0/0/0/0/0/1/2 MUC NAP NAP GVA GVA MUC
Window 01/11 02/11 03/11 04/11 05/11 06/11 07/11 08/11 09/11 10/11 11/11 12/11 13/11 14/11
01/11 02/11 03/11 04/11 05/11 06/11 07/11 08/11 09/11 10/11 11/11 12/11 13/11 14/11
Assign value: 0/0/0/0/0//1/2. Crew filter: On
SVO - FRA LH 3211 -1 J 123.56. A320 LH3306 0 F000 C144 M000 1/0/1/0/0//1/2
Gmt : 1605 - 1920 GDOR 1 Date(GDOP): 931101 SSIM 320 area :EU LH LH
Local : 1905 - 2020 Crew comp: booked:0/0/0/0/0//1/2
931101 - 931114 : READY
A320Nov01No cab14_scrat PTV
352 rows, Dated CRRs 931101 - 931104
0 - 931101 - 931114

The resulting optimization problem

$$\begin{aligned}
\text{minimize} \quad & 2x_1 + 2x_2 + 2x_3 + 2x_4 + x_5 + x_6 + x_7 + x_8 + 2x_9 + 2x_{10} \\
& + 2x_{11} + 2x_{12} + 2x_{13} + 2x_{14} + 2x_{15} + 2x_{16} + 2x_{17}
\end{aligned}$$

subject to

$$\begin{aligned}
x_1 + x_2 + x_3 + x_4 + x_9 + x_{10} &= 1 \\
x_1 + x_2 + x_3 + x_4 + x_9 + x_{10} &= 1 \\
x_2 + x_5 + x_6 + x_8 + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} &= 1 \\
x_2 + x_3 + x_5 + x_8 + x_{11} + x_{13} + 2x_{14} + 2x_{15} + x_{16} + x_{17} &= 1 \\
x_3 + x_4 + x_7 + x_8 + x_{10} + x_{13} + x_{14} + 2x_{15} + x_{16} + 2x_{17} &= 1 \\
x_4 + x_6 + x_7 + x_8 + x_{10} + x_{12} + x_{13} + x_{15} + x_{17} &= 1
\end{aligned}$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17} \in \{0, 1\}$$

PAROS

Prereq: Math & data structure

Courses and Programs

CS bachelor and master (GU)

Core:

- *Algorithms* TIN093/DIT602
- Algorithms, advanced TDA251/DITDIT281

"CS-all" (MPALG) master (CTH)

Data science and AI master (CTH)

Related:

- Algorithms for Machine learning and inference TDA231/DIT380
- Applied Machine learning DAT340/DIT866
- Discrete optimization TDA206/DIT370
- *Mathematical modelling and problem solving*, Applied mathematical thinking

Applied data science master (GU)

More Courses

- *Introduction to data science and AI* DAT405 (new)
- Techniques for large scale data DAT345/DIT871
- Design of AI systems (new)
- Computational methods for bioinformatics TDA507/DIT741
- Natural language processing with machine learning (new)
- Bachelor thesis and master´s thesis projects
- Project course and seminar course

Research Areas within the Division DSAI

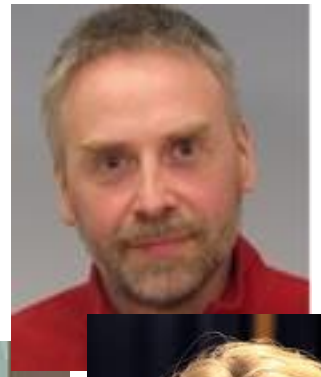
Machine learning, Artificial intelligence, Bioinformatics, ***Algorithms***, Graph theory, Randomized algorithms, Combinatorial optimization, Natural Language processing, Reinforcement learning, Unsupervised learning, Neural networks, Self-driving cars, Applications of machine learning in health, ***Mathematical modelling*** ...

Talks earlier in this seminar series

https://www.chalmers.se/en/departments/cse/organisation/ds/Pages/default.aspx

Division Data science and AI



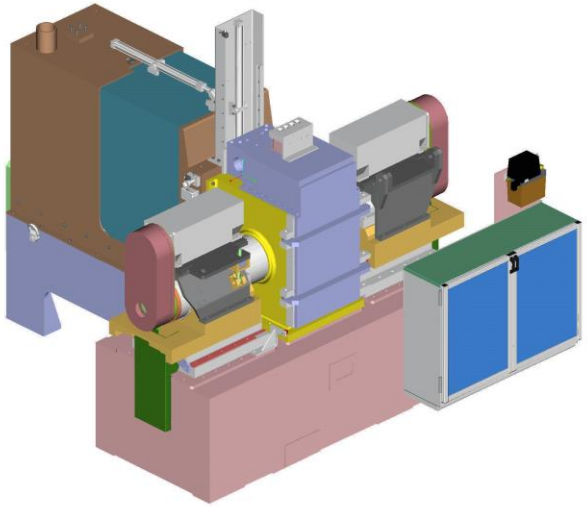


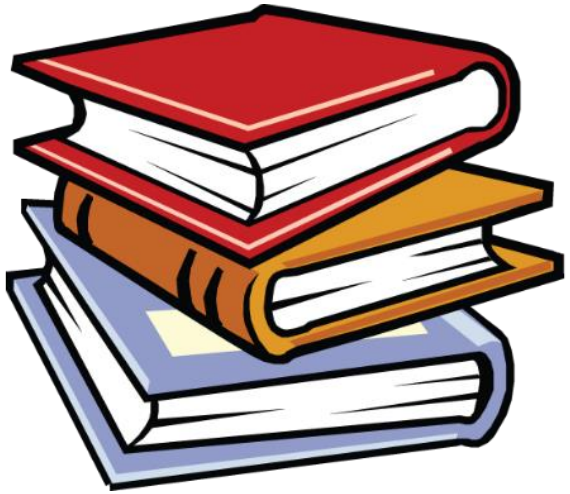




Graham Kemp, Alexander Schliep, Dag Wedelin, Birgit Grohe*, Ashkan Panahi*,
Christos Dimitrakakis, Devdatt Dubhashi, Richard Johansson, Claes Strannegård*, Fredrik Johansson*
Morteza Chehregani, Peter Damaschke (+Phd students and postdocs)

Algorithms Courses – What´s in it?





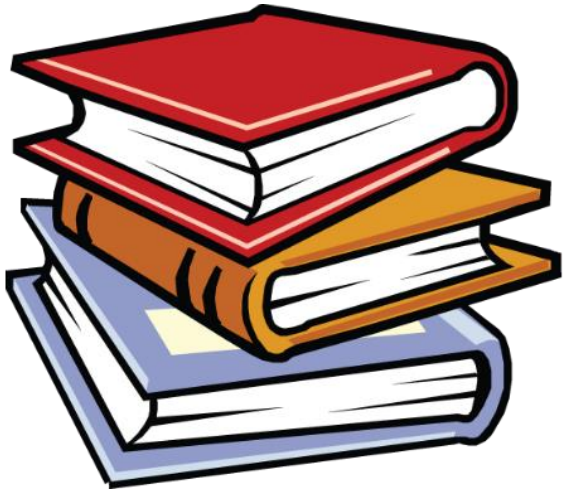
Course Content – Algorithms Toolbox

Algorithm design principles

- Greedy
- Divide and Conquer
- Dynamic Programming
- Complete Search
- Heuristics
- …

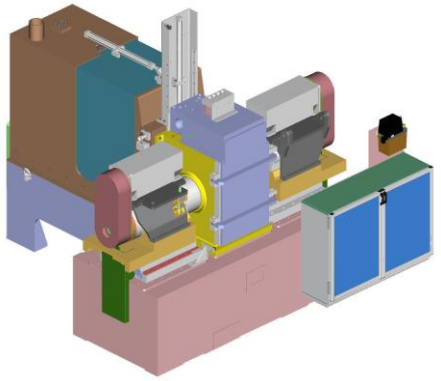
Course Content: Standard Problems

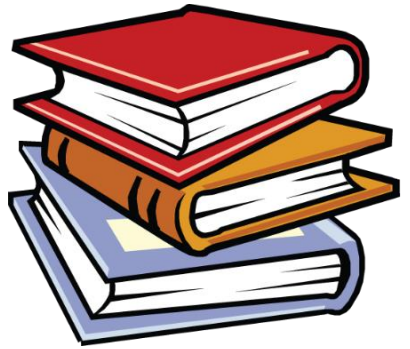
- Searching
- Sorting
- Finding shortest path (SP)
- Finding longest path
- Max flow problem
- Travelling salesperson problem (TSP)
- Graph Coloring
- Satisfiability problem (SAT)
- …

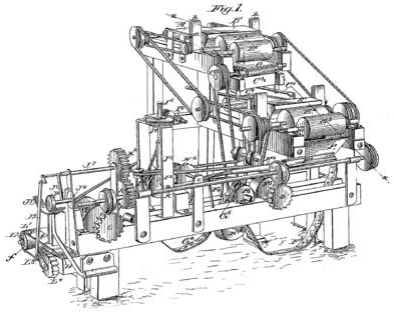


Course Content: Standard Algorithms

- Binary Search
- Insertion Sort, Quicksort …
- Bredth first search ...
- Dijkstras Algorithm
- Floyd Warshall Algorithm
- Ford Fulkerson Algorithm
- …
- …
- Randomized Algorithm for Scheduling Multi-Resource Jobs in the Cloud?







Good Algorithms?

”[…] We want *good* algorithms in some loosly defined aestetic sense. One criterion is the length of the time to perform the algorithm […] Other criteria are adaptability of the algorithm to computers, its simplicity and elegance etc ”

Knuth 1973:3