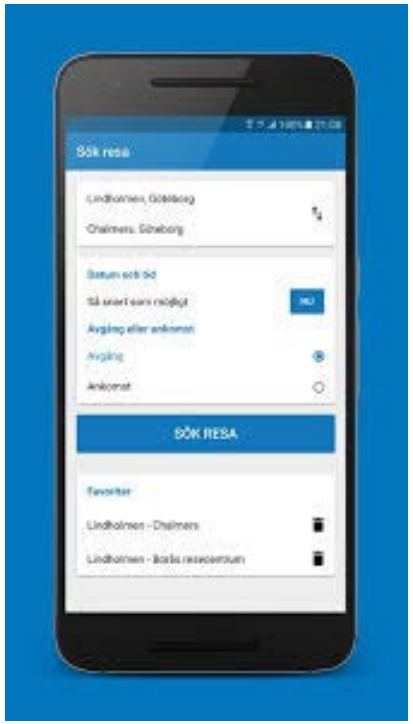
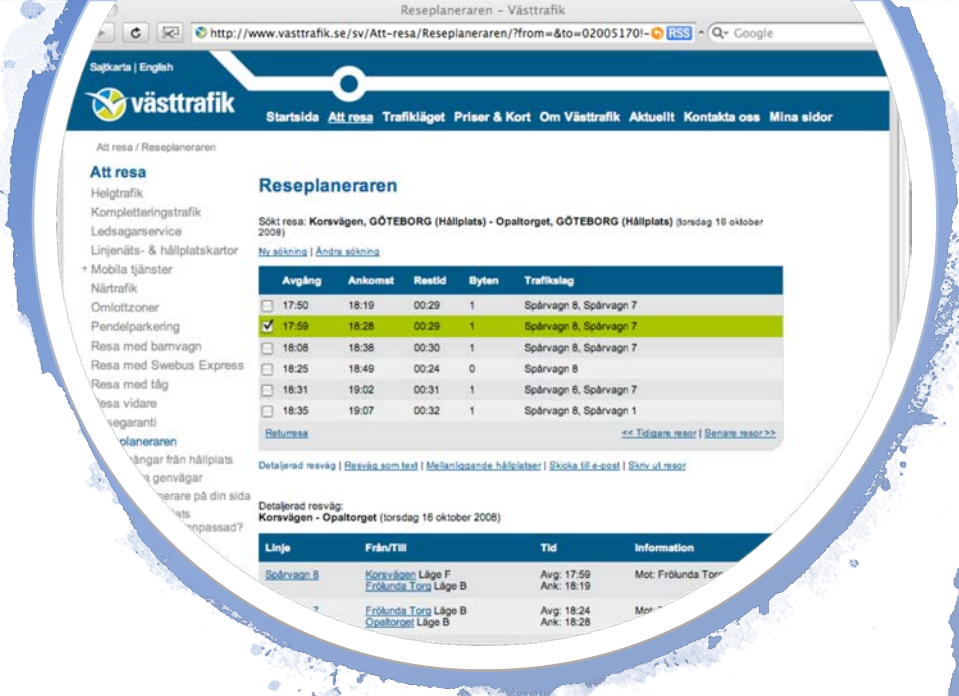
Algorithms

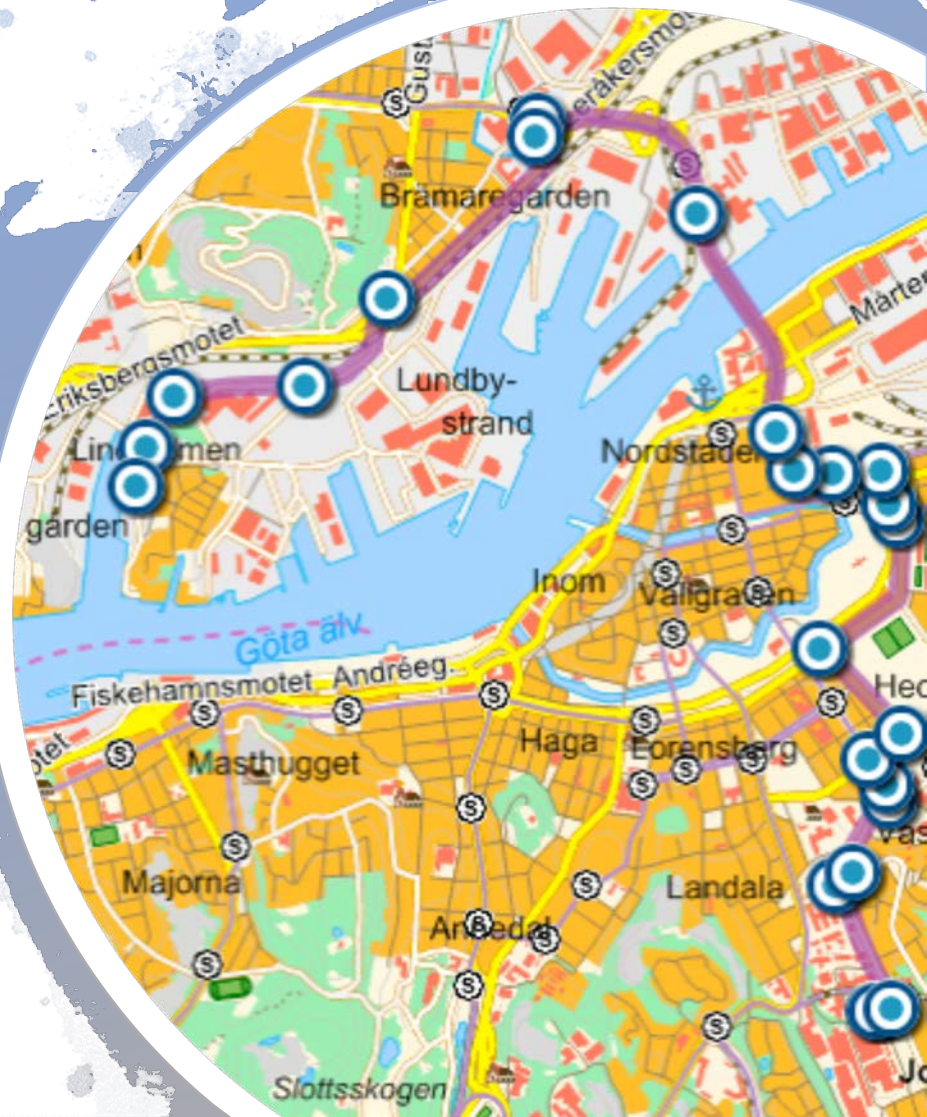
Birgit Grohe

2019-05-06

Used an Algorithm Today?



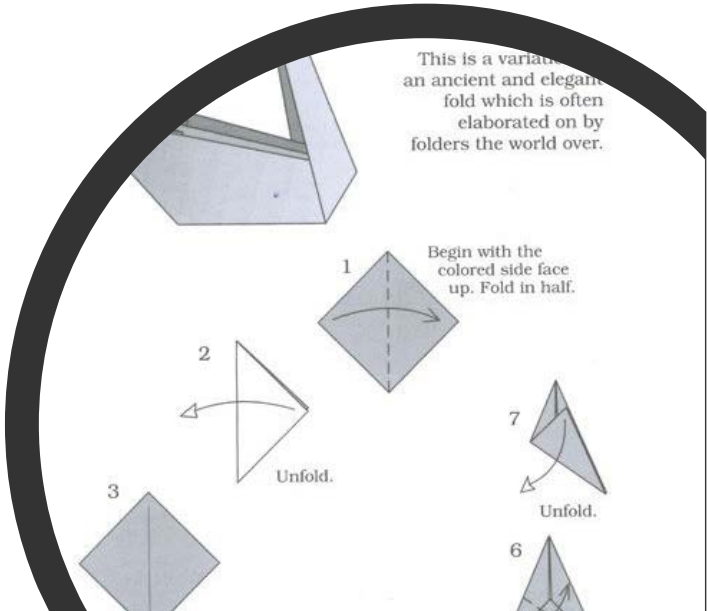




Used an Algorithm Today?

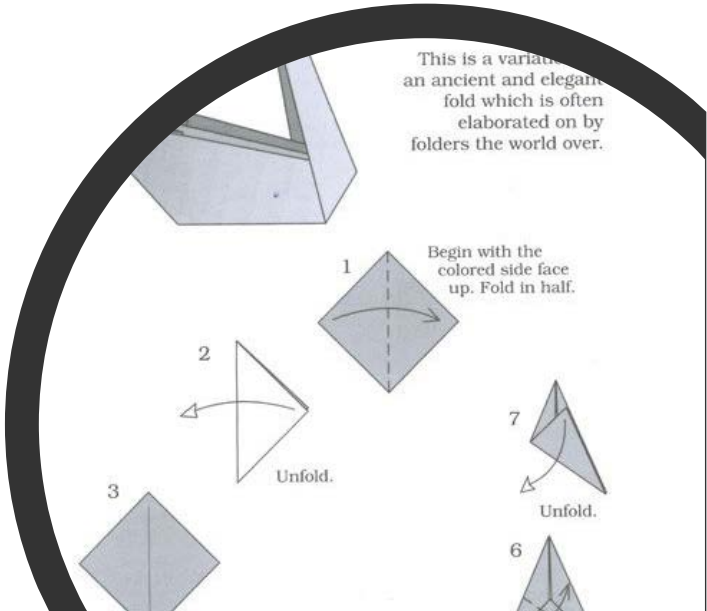
Used an algorithm today?

- 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?

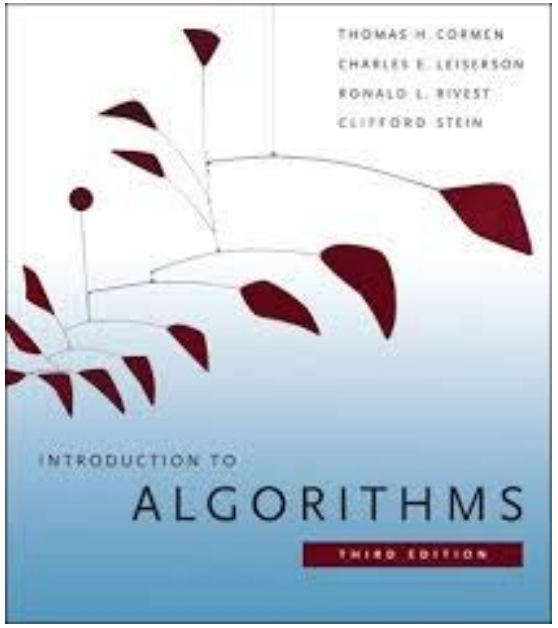
An Algorithm is a well-defined computational procedure that takes some value, or a set of values, as input and

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



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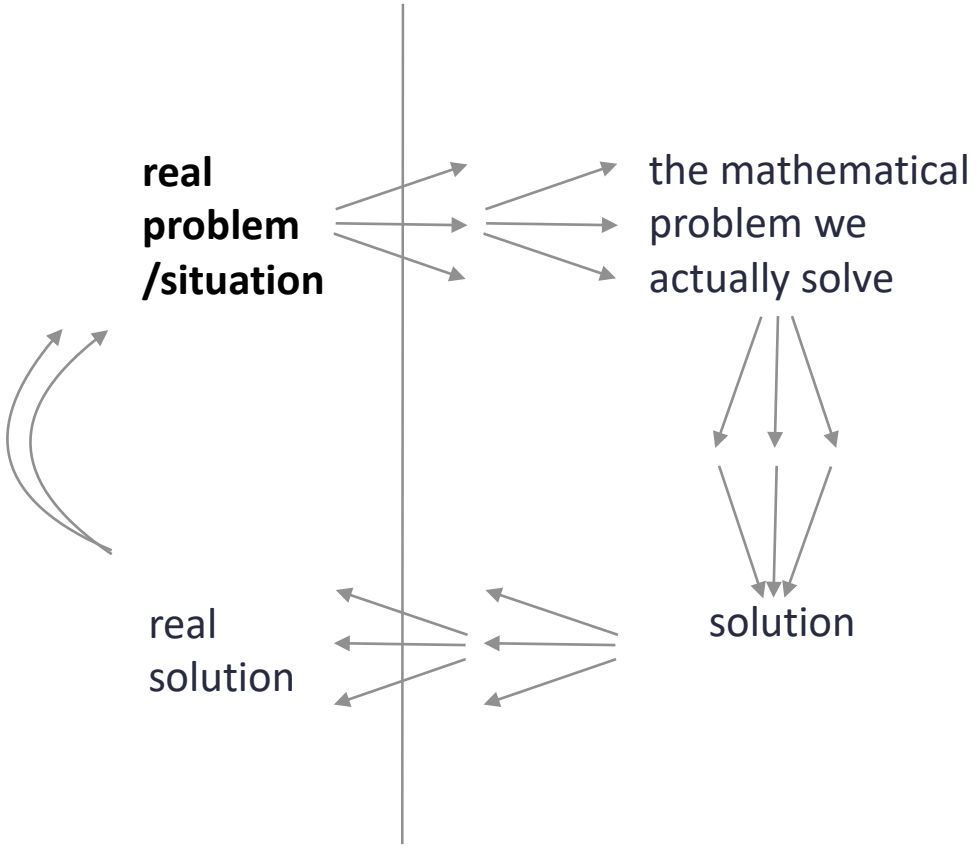
Algorithms in relation to modelling and problem solving



An iterative and creative design process!

First Known Algorithm?

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

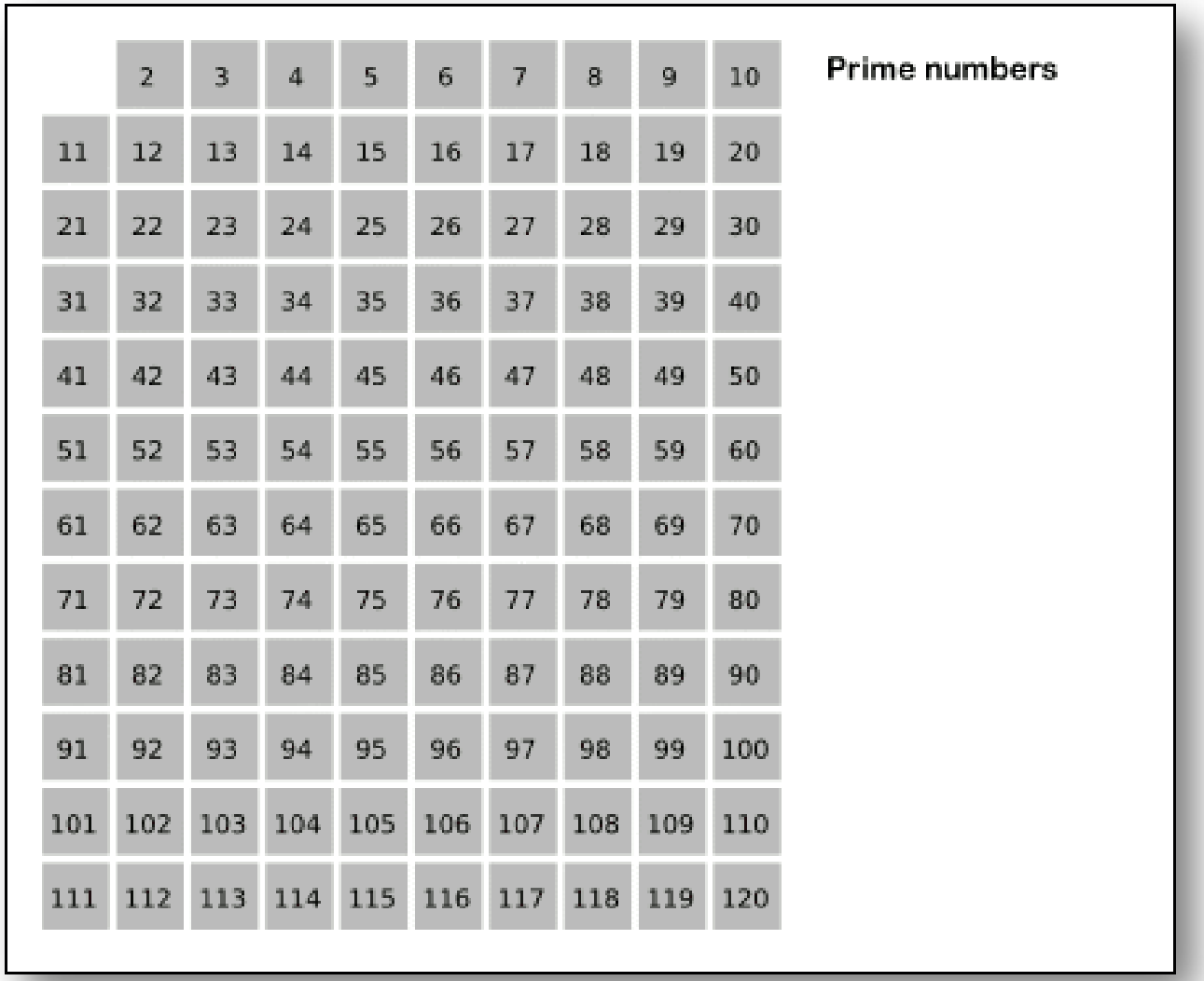
Euclid´s Elements

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

Animations:

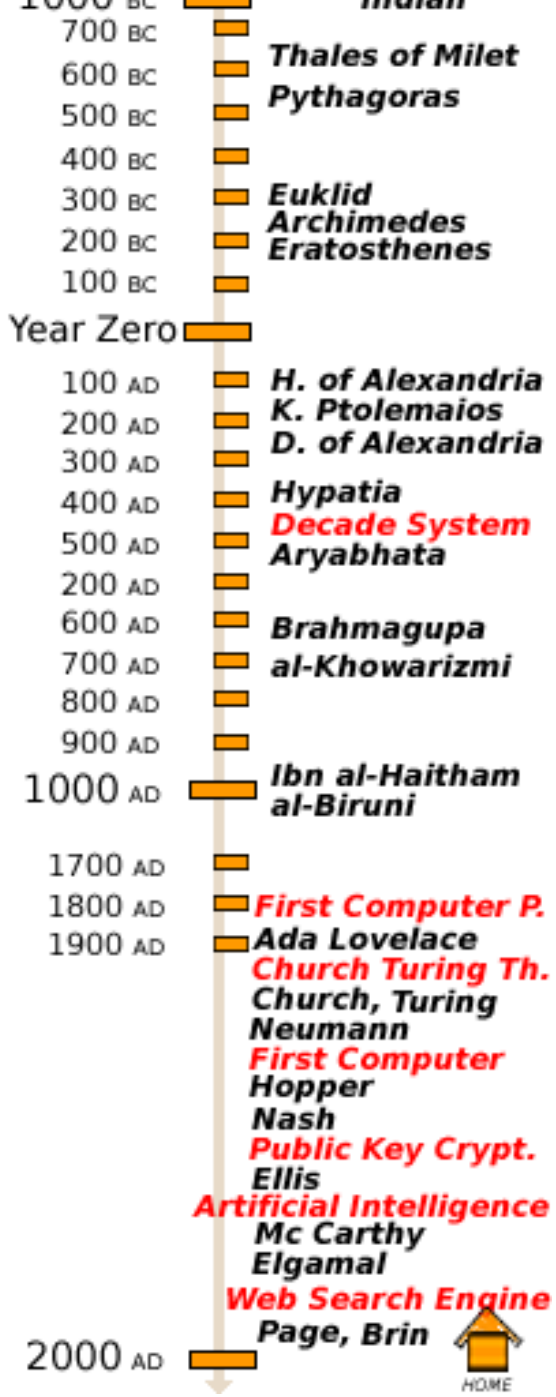
https://en.wikipedia.org/wiki/Algorithm (GCD)
https://en.wikipedia.org/wiki/Sieve_of_Eratosthenes

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

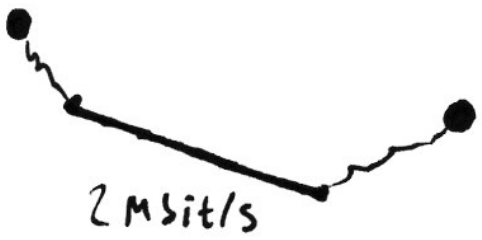


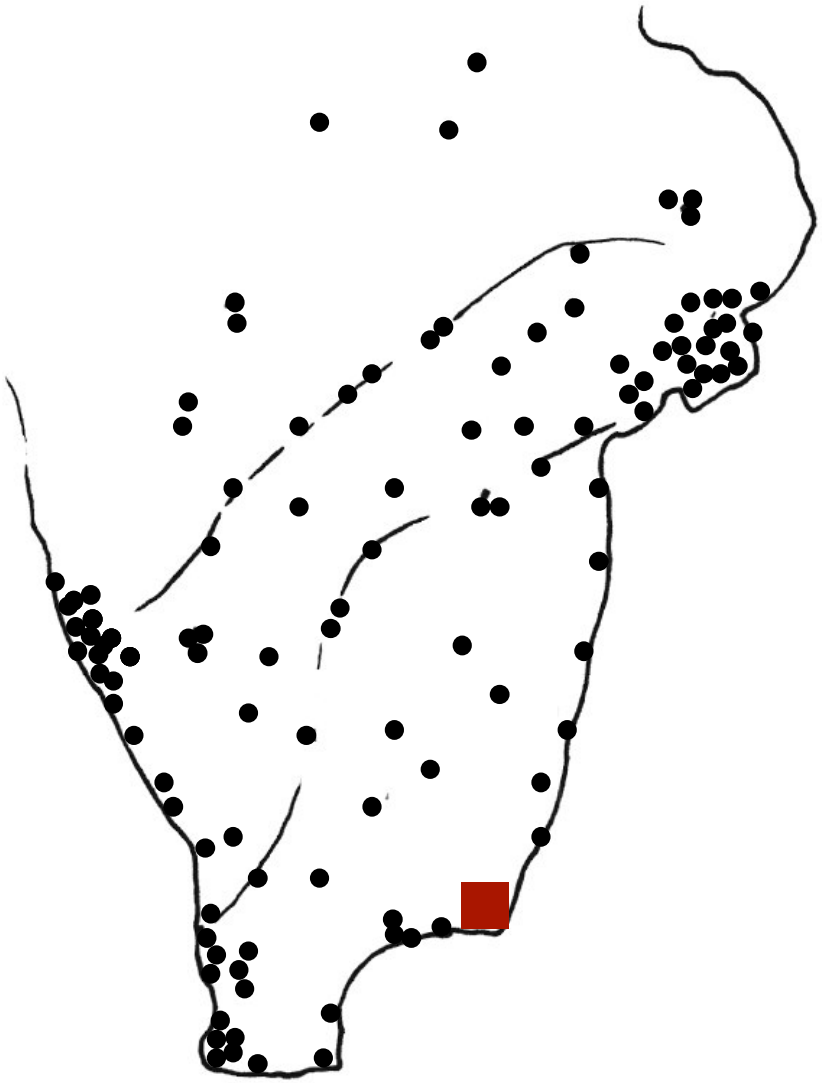
http://cs-exhibitions.uni-klu.ac.at/index.php?id=193

Telephone operator problem (real applied problem)

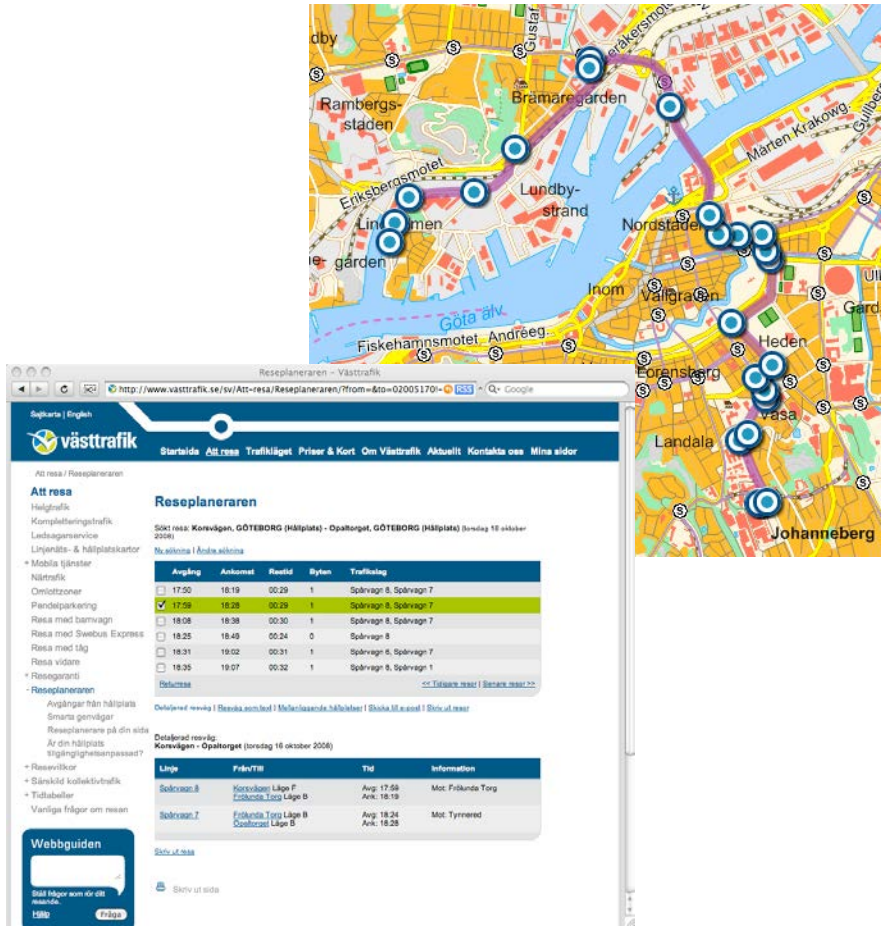
A Swedish mobile phone operator needs to connect all base station to its main switch.

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



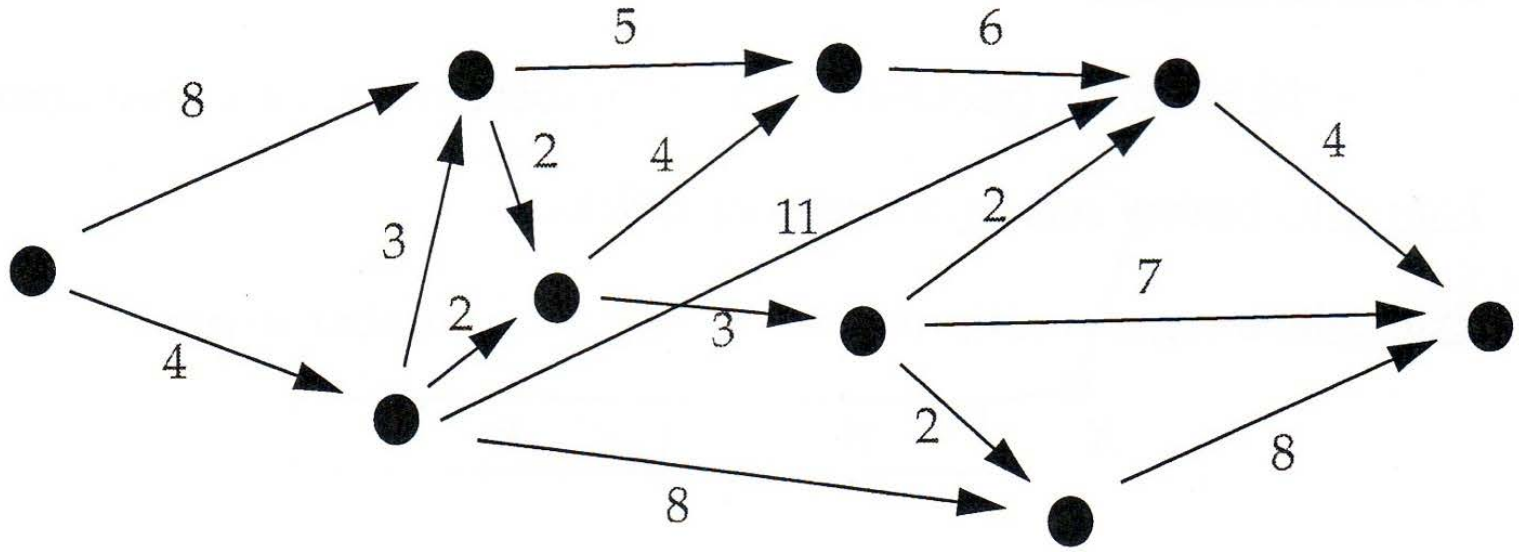


The Shortest Path Problem



How solve?

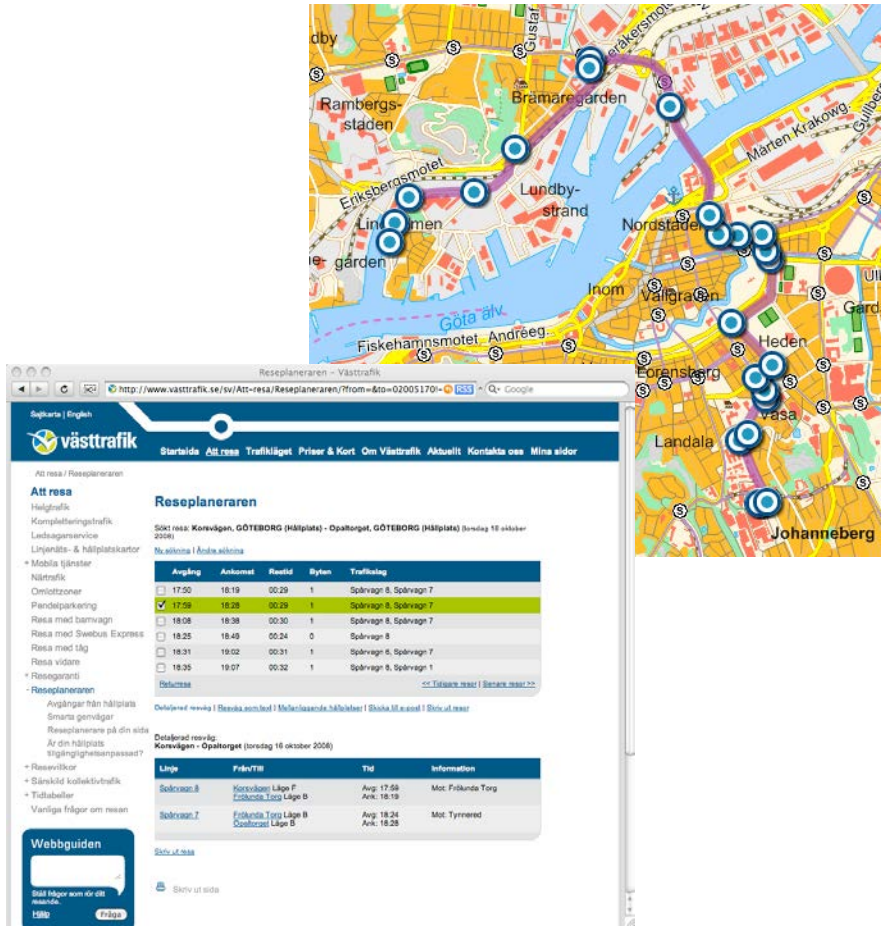
Solving the directed shortest path problem with dynamic programming



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)

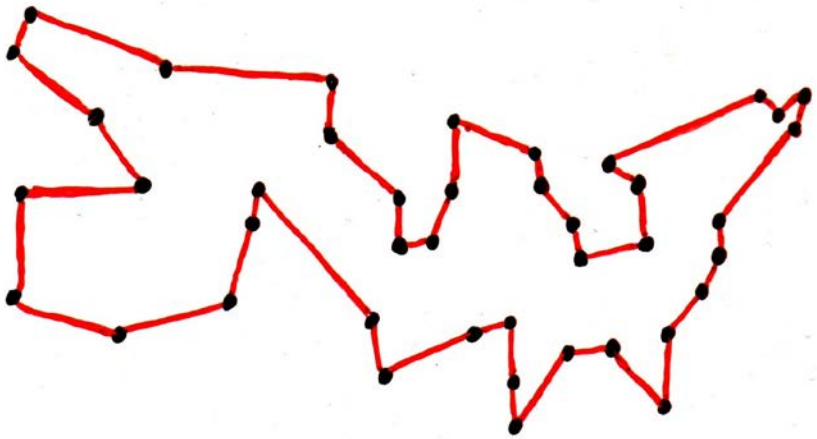
The Shortest Path Problem



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

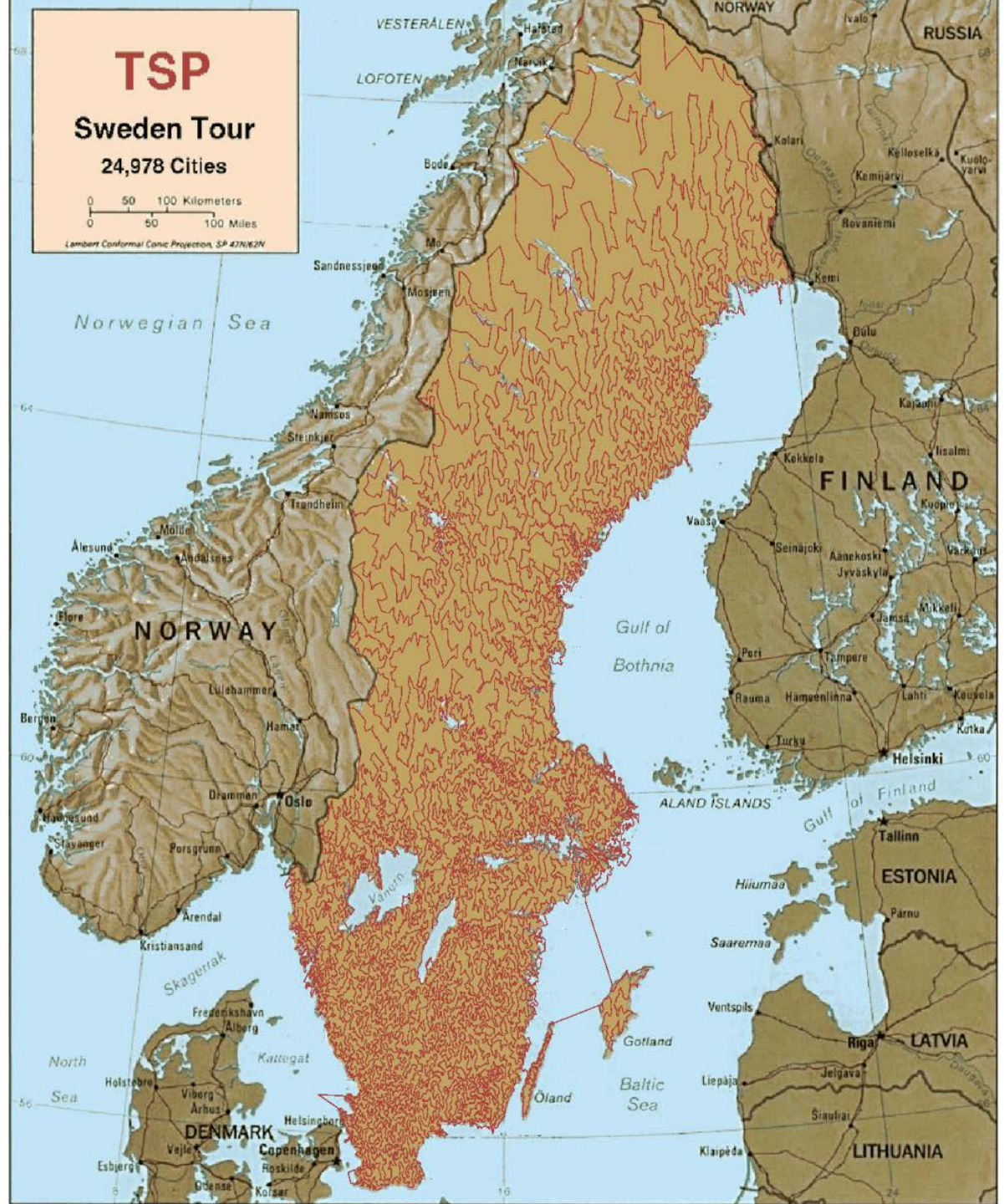
The Travelling Salesperson Problem



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


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

Graphic Pairing Construction
Data
Plan
Rule
APC
Report
Options
Help
15:25
Window
01/11
02/11
03/11
04/11
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07/11
08/11
09/11
10/11
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12/11
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14/11
01/11
02/11
03/11
04/11
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
Grt : 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 MTV
352 rows. Dated CRRs 931101 - 931104
0 931101 - 931114

The resulting optimization problem

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

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

PAROS

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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

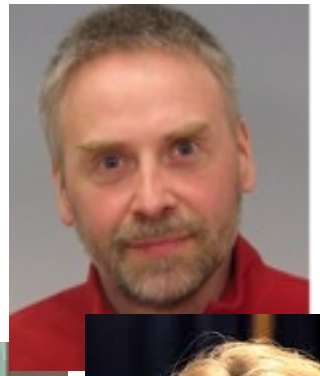
Research Areas within the Division DSAI

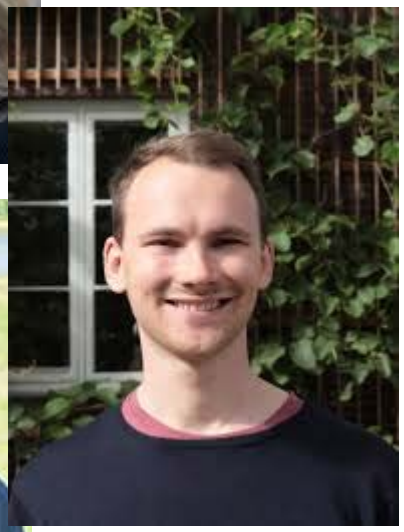
Machine learning, Artificial intelligence, Bioinformatics, ***Algorithms***, Graph theory, Randomized algorithms, Combinatorial optimization, Natural Language processing, Reinforcement learning, Unsupervised learning, Neural networks, Self-driving cars, Applications of machine learning in health, ***Mathematical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

Talks earlier in this seminar series

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

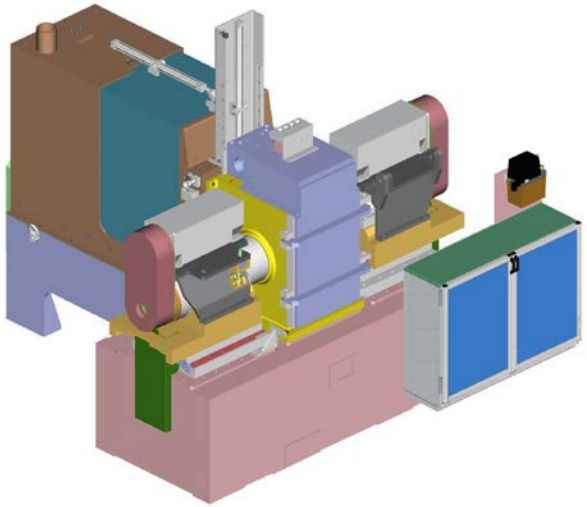
Division Data science and AI

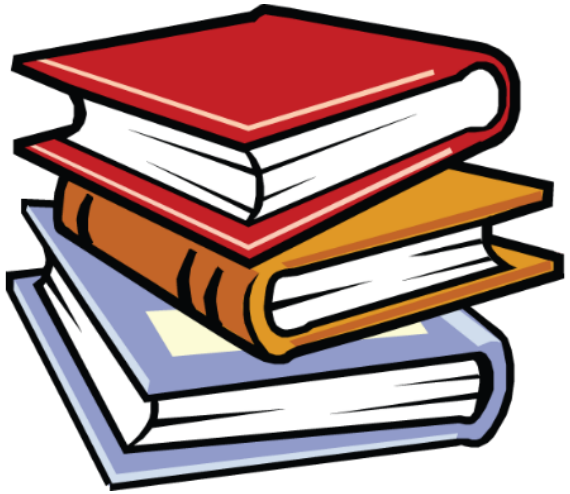




Graham Kemp, Alexander Schliep, Dag Wedelin, Birgit Grohe*, Ashkan Panahi*,
Christos Dimitrakakis, Devdatt Dubhashi, Richard Johansson, Claes Strannegård*, Fredrik Johansson*
Morteza Chehregani, Peter Damaschke (+Phd students and postdocs)

Algorithms Courses – What´s in it?





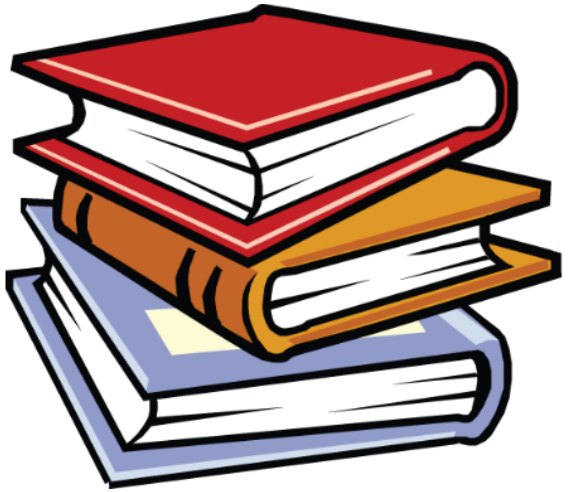
Course Content – Algorithms Toolbox

Algorithm design principles

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

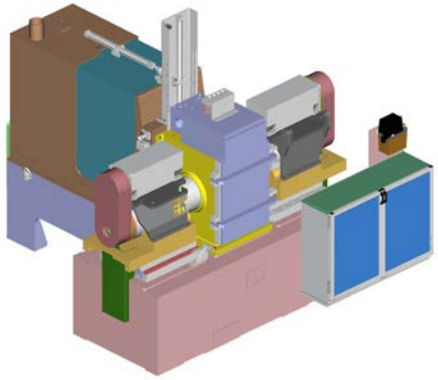
Course Content: Standard Problems

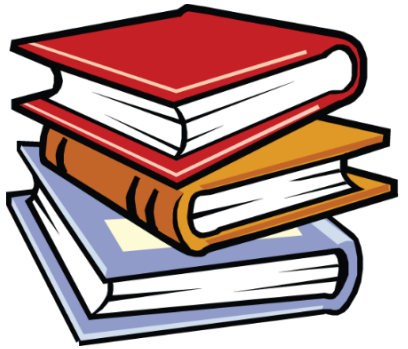
- Searching
- Sorting
- Finding shortest path (SP)
- Finding longest path
- Max flow problem
- Travelling salesperson problem (TSP)
- Graph Coloring
- Satisfiability problem (SAT)
- …

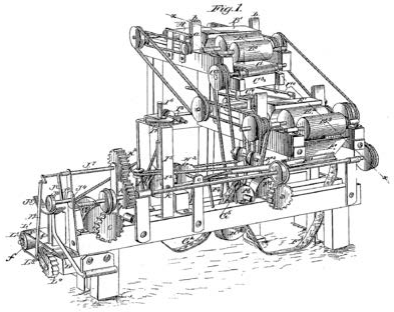


Course Content: Standard Algorithms

- 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