De onwaarschijnlijke evolutie van de informatietechnologie

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KU Leuven

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STADIUS
Center for Dynamical Systems, Signal Processing and Data Analytics

Menu

- From science to technology
- The fourth paradigm
- AI waves
- Use Cases
- Government action programs

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The science

1880: Maxwell's laws (electro-magnetism)

1905: Quanta: Planck and Einstein

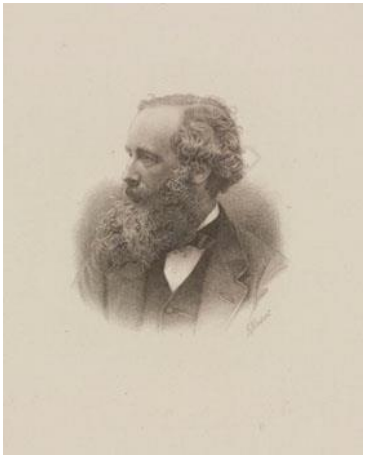
1910: Atom model Bohr

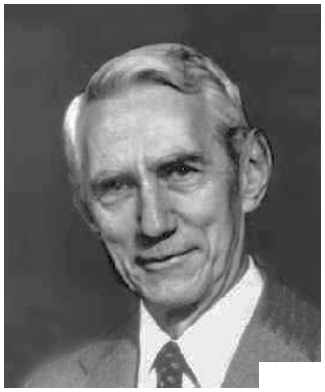
1930: Quantummechanics of Heisenberg, Schrödinger,…

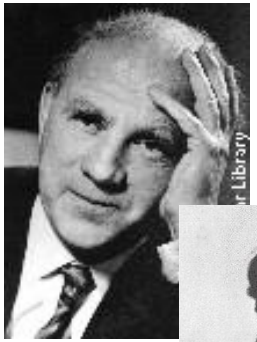
1940: Computer (principle) of Turing and von Neumann

1948: Information theory of Shannon

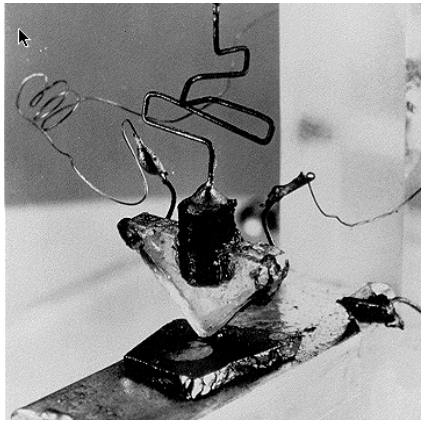
1950: Transistor of Shockley, Bardeen,…

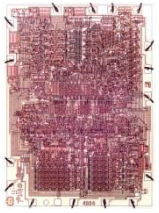


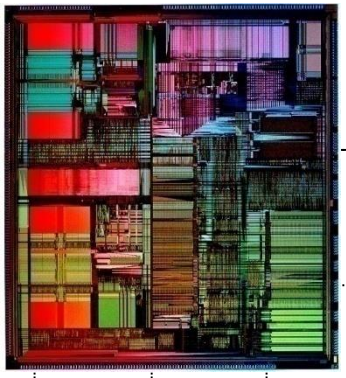


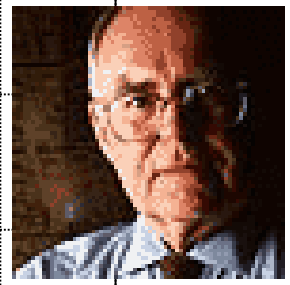


Technology and Engineering Design:
The third industrial revolution (1945…)

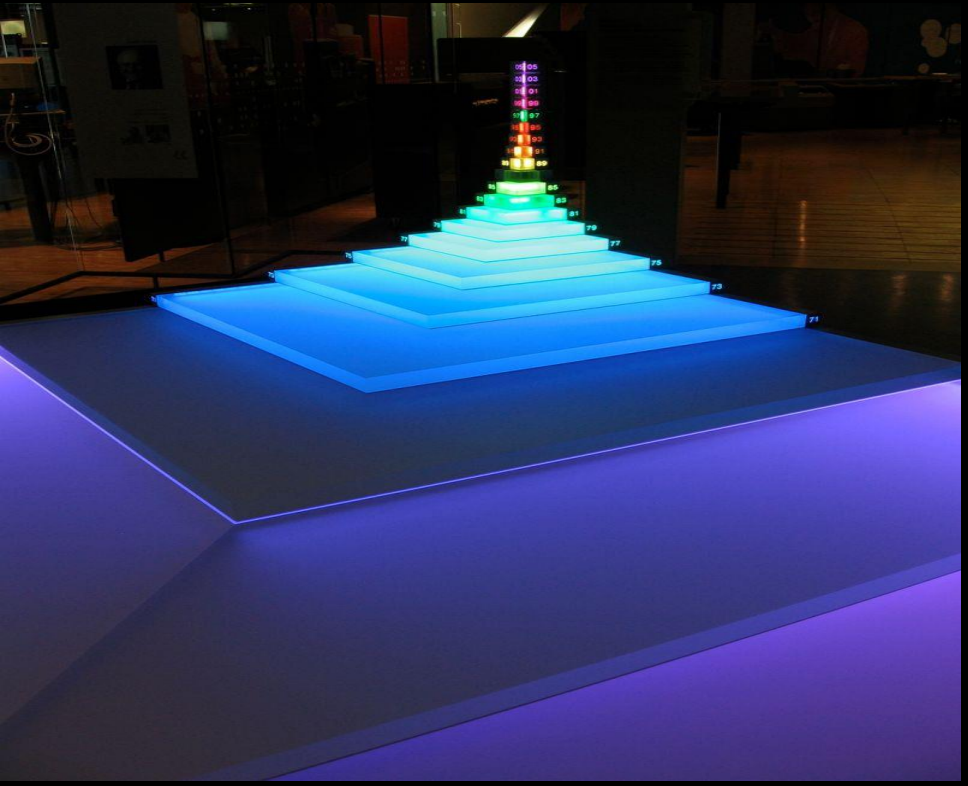






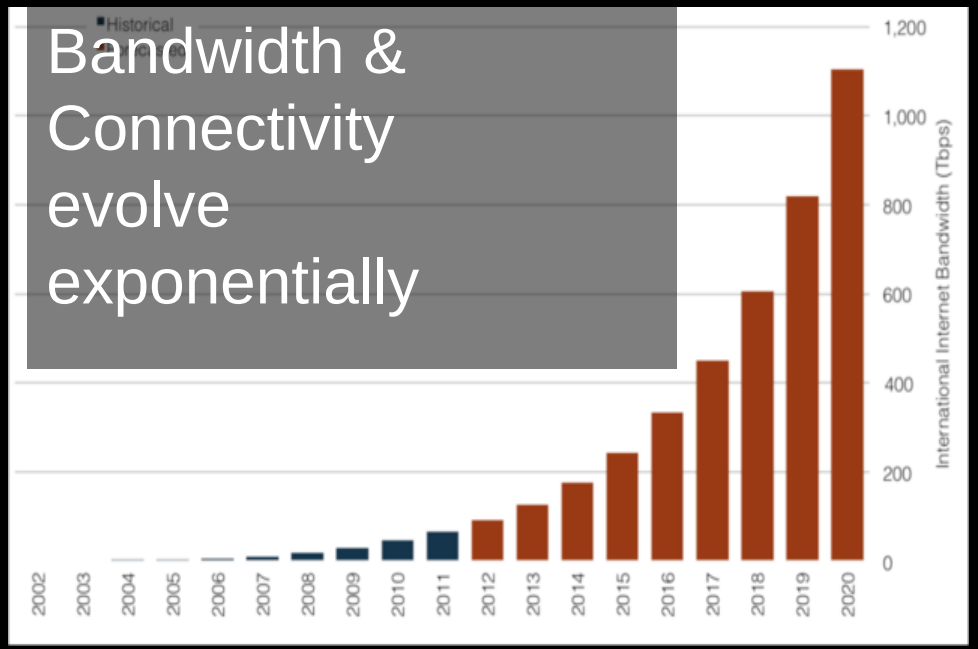


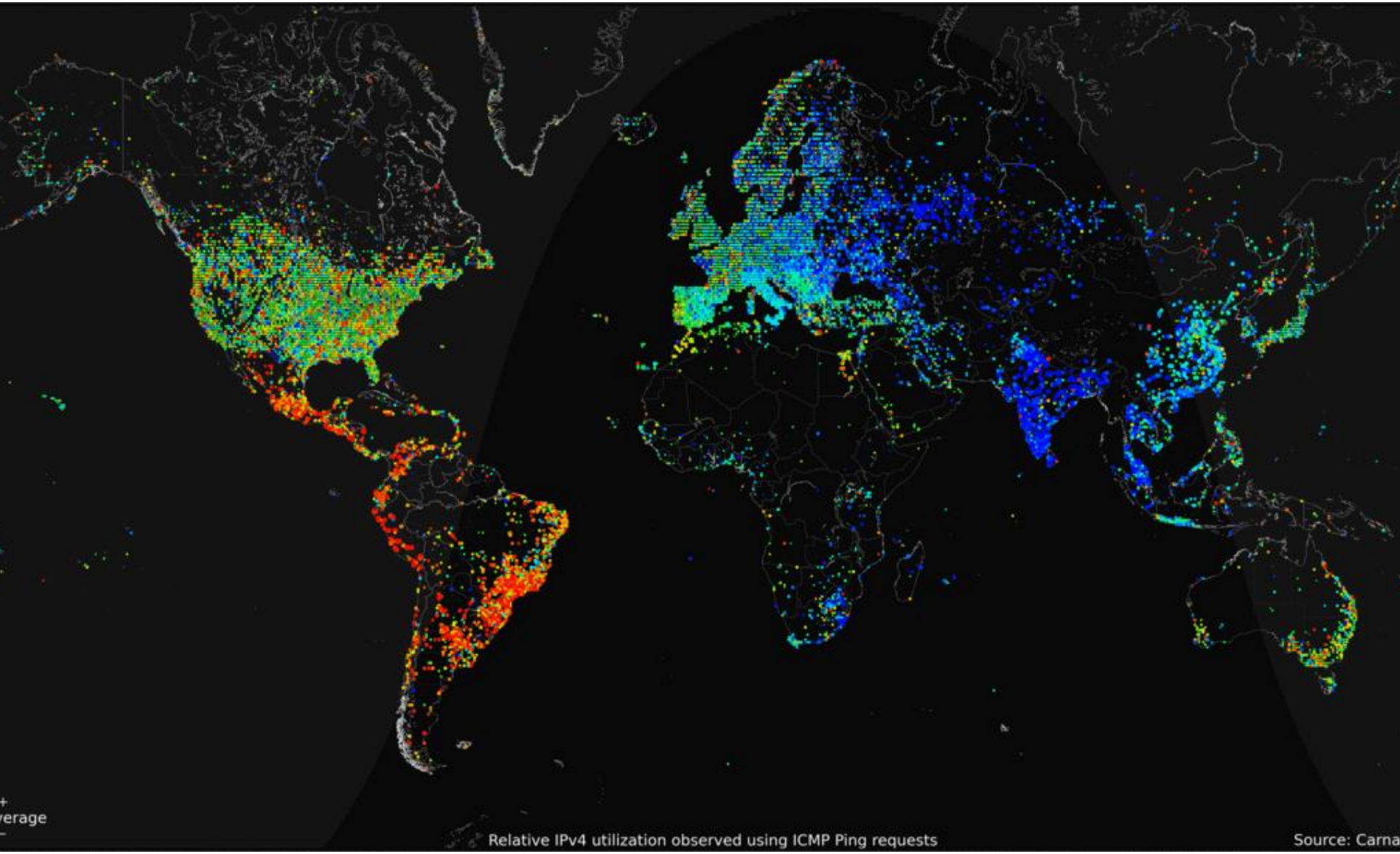
Computational power x 2 every 18 months

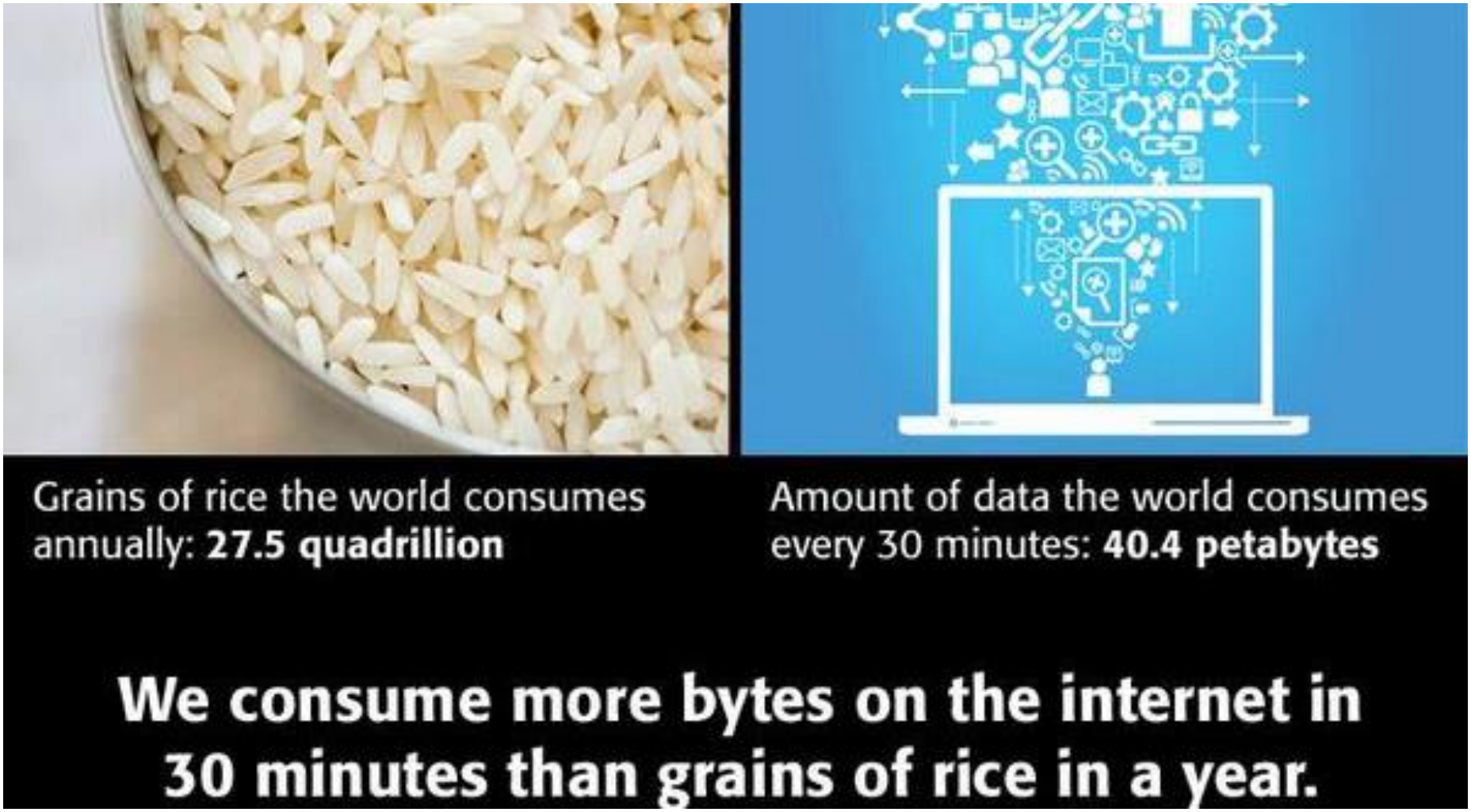


Moore's law:
computing power
doubles
every 18 months

Bandwidth &
Connectivity
evolve
exponentially




+
verage
-
Relative IPv4 utilization observed using ICMP Ping requests
Source: Carna



1 million = 1 000 000
1 billion = 1 000 000 000
1 trillion = 1 000 000 000 000
1 quadrillion =
1 000 000 000 000 000

1 kB = 1 000
1 MB = 1 000 000
1 GB = 1 000 000 000
1 TB = 1 000 000 000 000
1 PB = 1 000 000 000 000 000

1 TB
= large university library
= 212 DVD discs
= 1430 CDs
= 3 year music CD quality

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The Fourth Paradigm

Paradigm	Time Ago	Method
First	A millenium	Empirical
Second	A few centuries	Theoretical
Third	A few decades	Computational
Fourth	Today	Data-driven

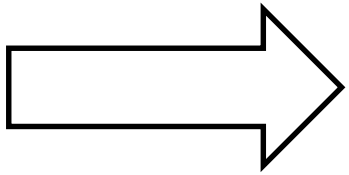
Evolution

From

I have a hypothesis

⇩

I need data to check it



To

I have data

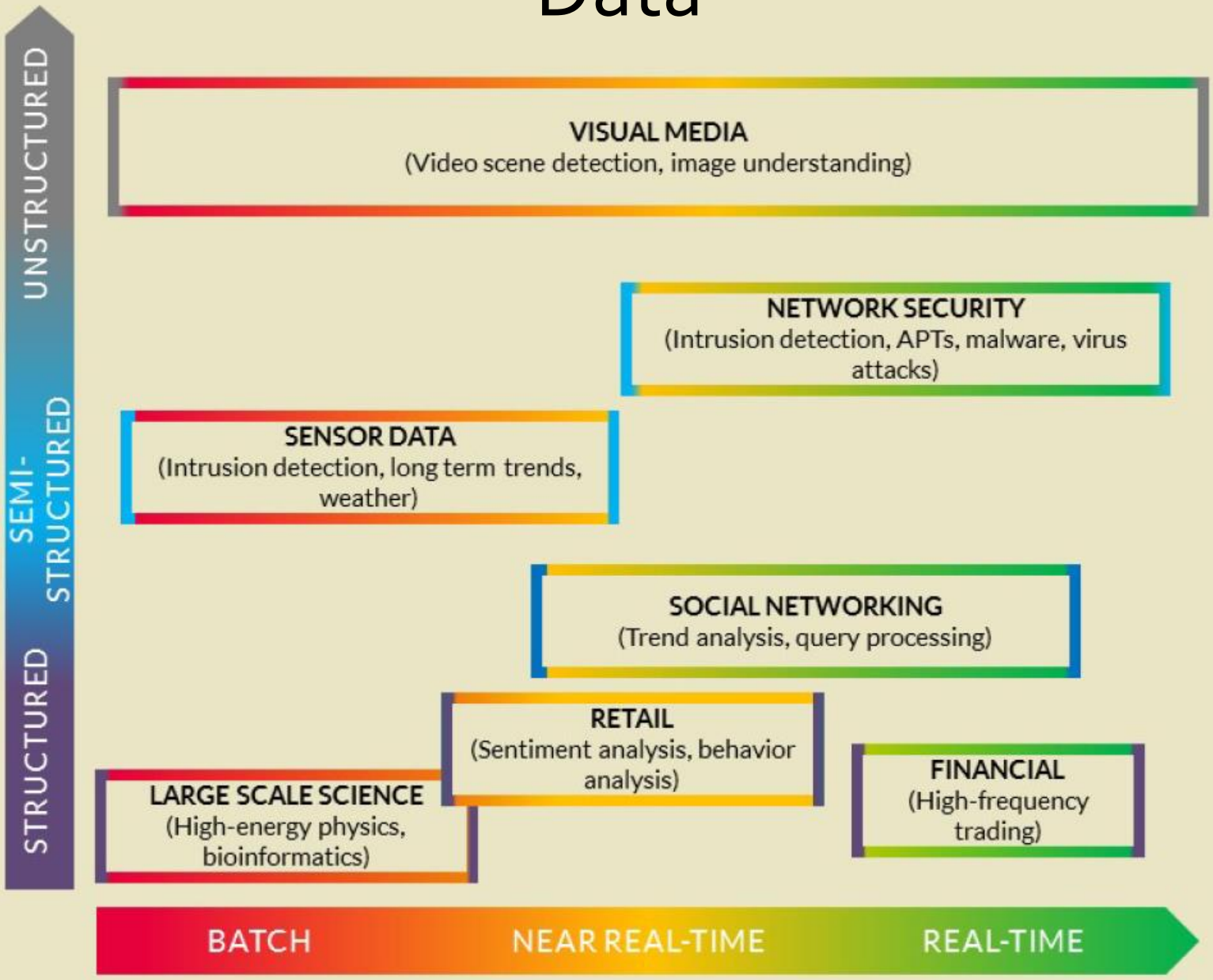
⇩

Which hypotheses can I check?

⇨ Data first!


1
Data
2
Compute Infrastructure
3
Storage Infrastructure
4
Analytics
5
Visualization
6
Security & Privacy
Big Data

Data


UNSTRUCTURED
SEMI-STRUCTURED
STRUCTURED
VISUAL MEDIA
(Video scene detection, image understanding)
NETWORK SECURITY
(Intrusion detection, APTs, malware, virus attacks)
SENSOR DATA
(Intrusion detection, long term trends, weather)
SOCIAL NETWORKING
(Trend analysis, query processing)
RETAIL
(Sentiment analysis, behavior analysis)
FINANCIAL
(High-frequency trading)
LARGE SCALE SCIENCE
(High-energy physics, bioinformatics)
BATCH
NEAR REAL-TIME
REAL-TIME

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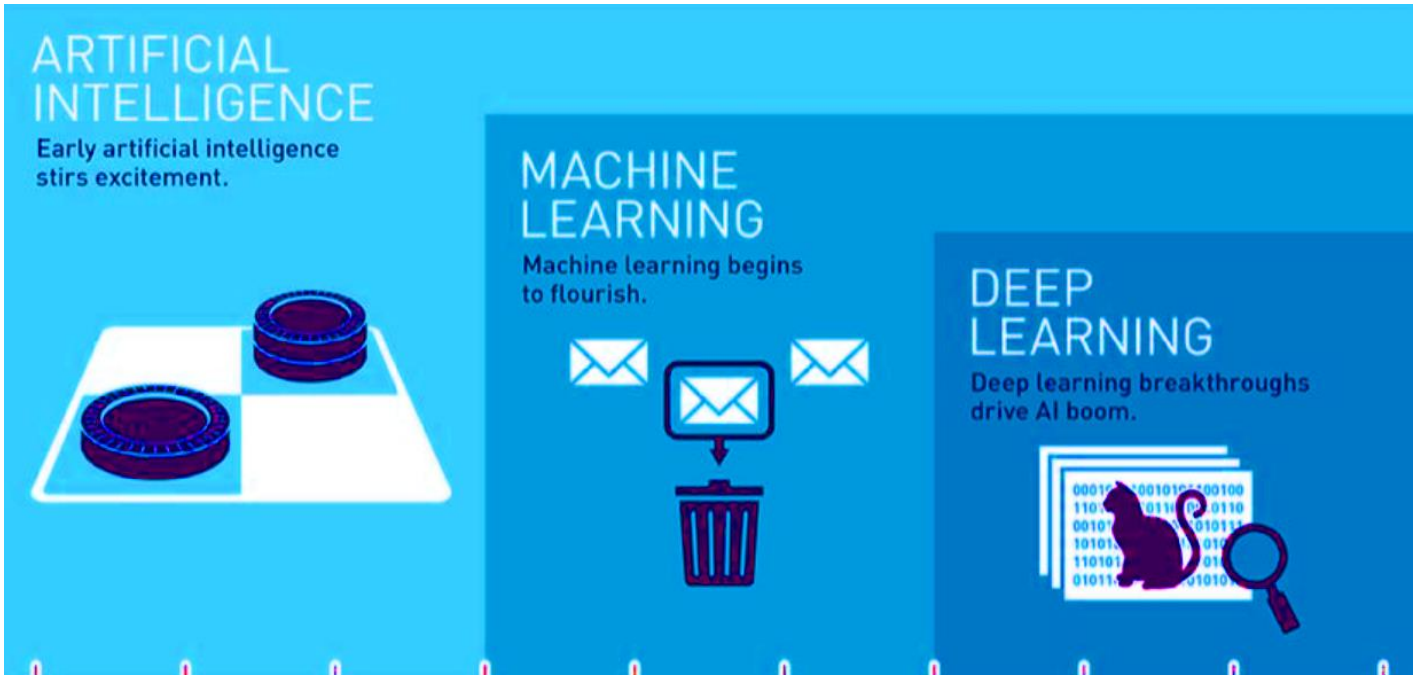
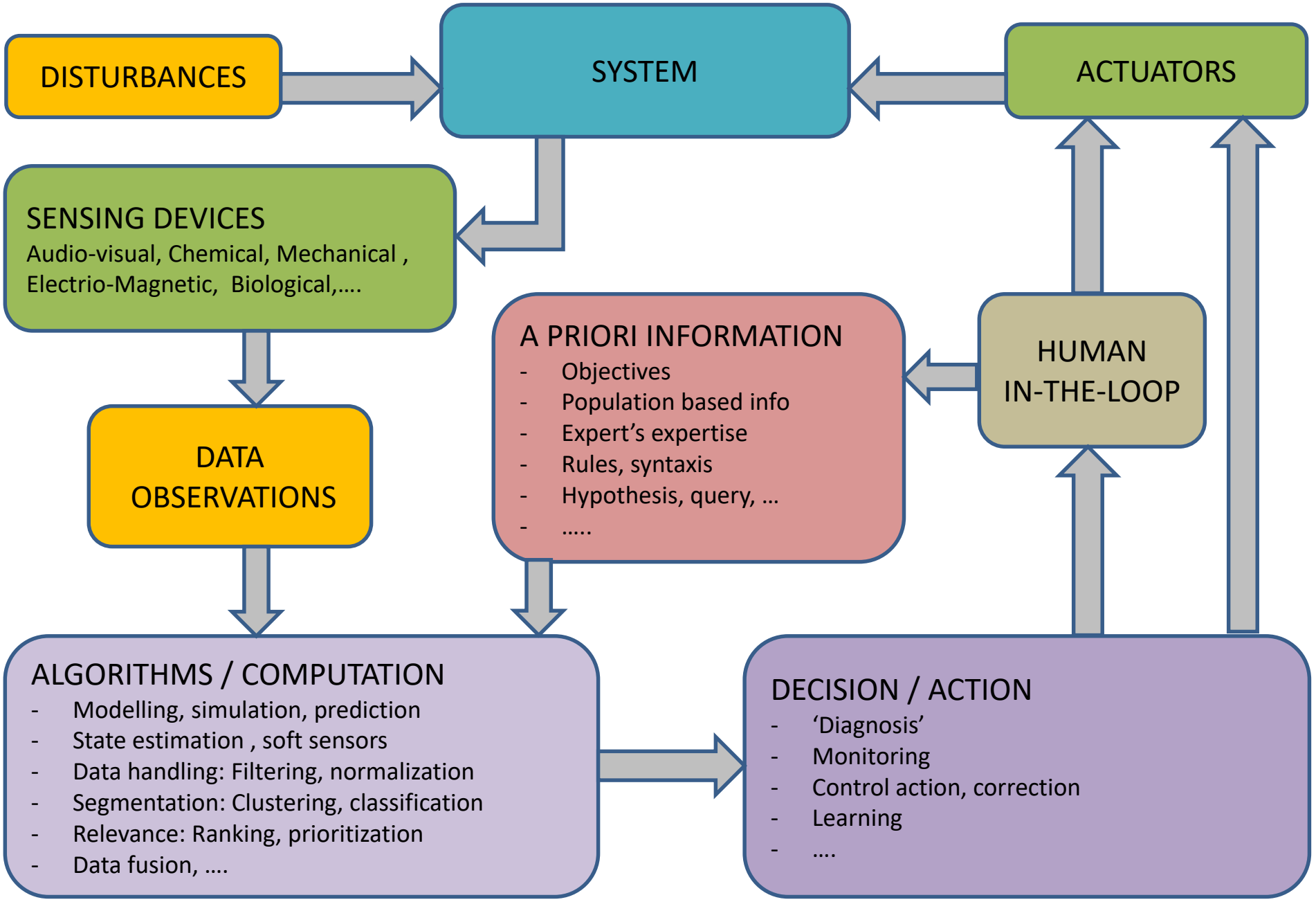


Expert Systems **Data** **Computations**

REASONING BASED → **HYBRID AI** ← **EVIDENCE DATA-BASED**

AI enabled Decision Support Systems



Main tasks

Prediction

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Regression

Segmentation

⇩

Clustering

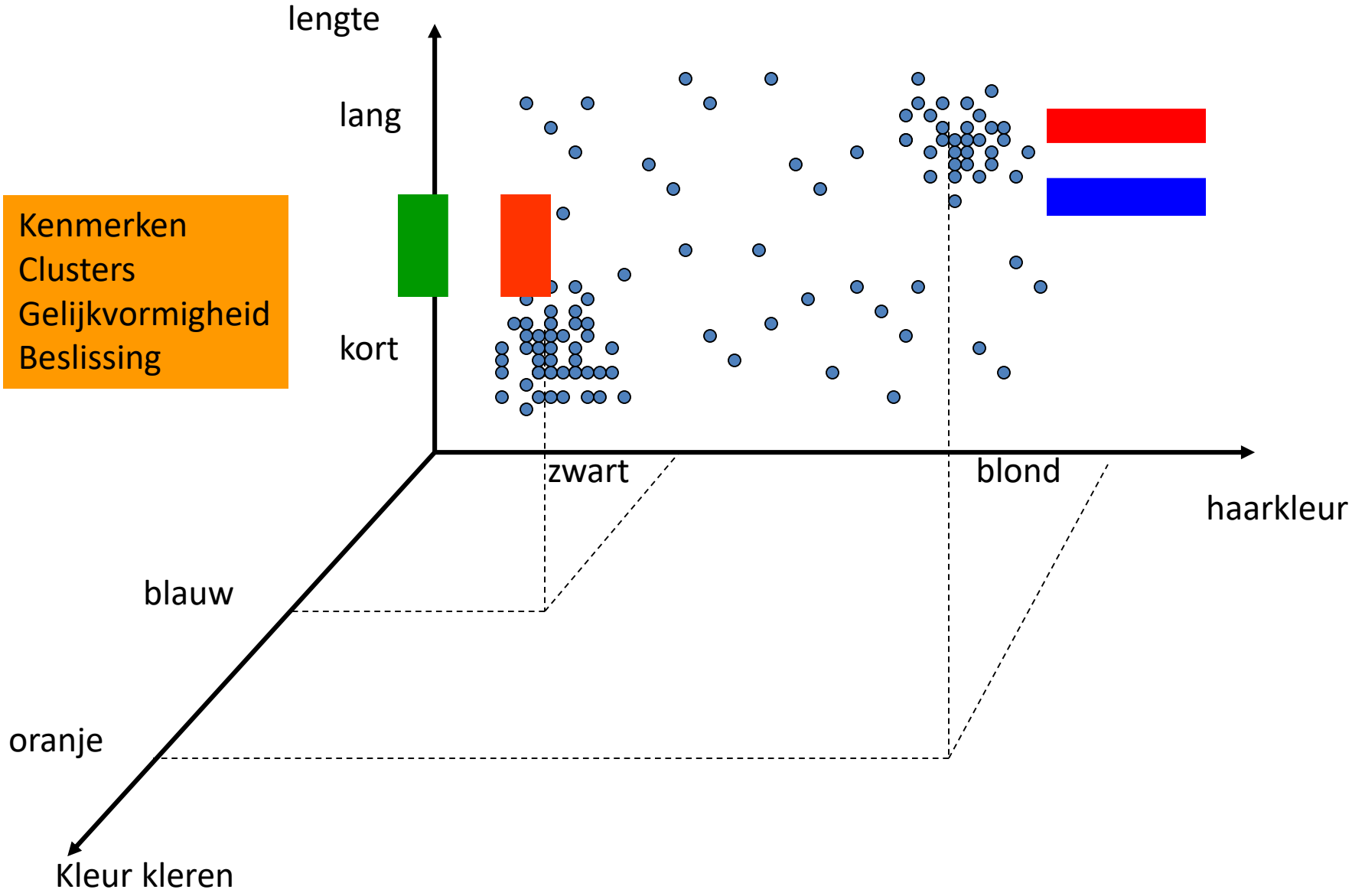
Classification

Anomalies

⇩

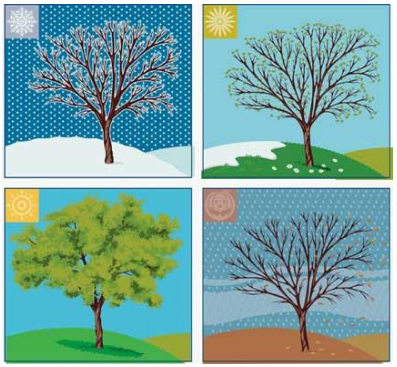
Detect outliers

Methodes om te clusteren



Main tasks

Filtering effects



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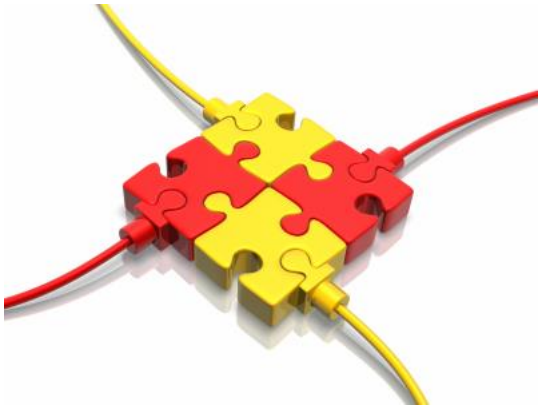
Normalization

Assess relevance

⇩

Ranking

Combining info



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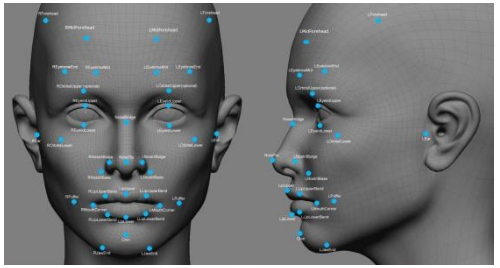
Data fusion

Objectives - ICT

Communication networks

Facial recognition



Home automation

Digital signing

Data center optimization

Objectives - Finance

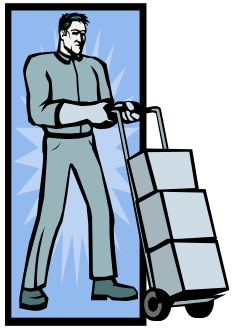
Fraud detection

Credit worthiness

Risk assessment

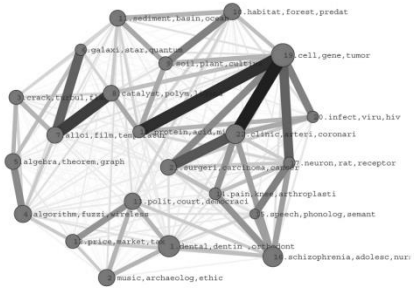
Portfolio management

Just-in-time production

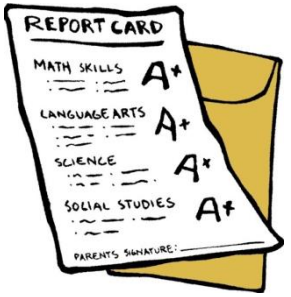


Objectives - Education

Scientometrics

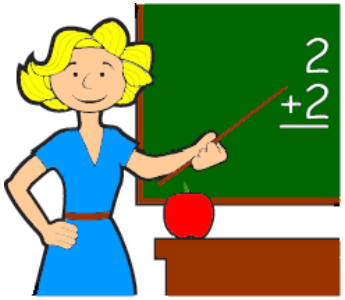


Grading



Detecting plagiarism

Teacher performance



Student performance

Objectives – Smart Cities

Predictive maintenance

Smart lighting

Flood prediction

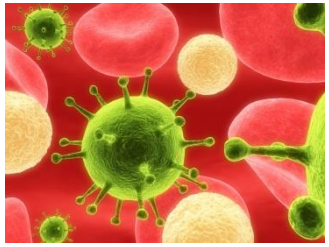
Traffic management

Electricity Demand

Objectives – Health

Diagnostics

Disease spreading



Genome sequencing

Tumour detection

Medical fraud detection

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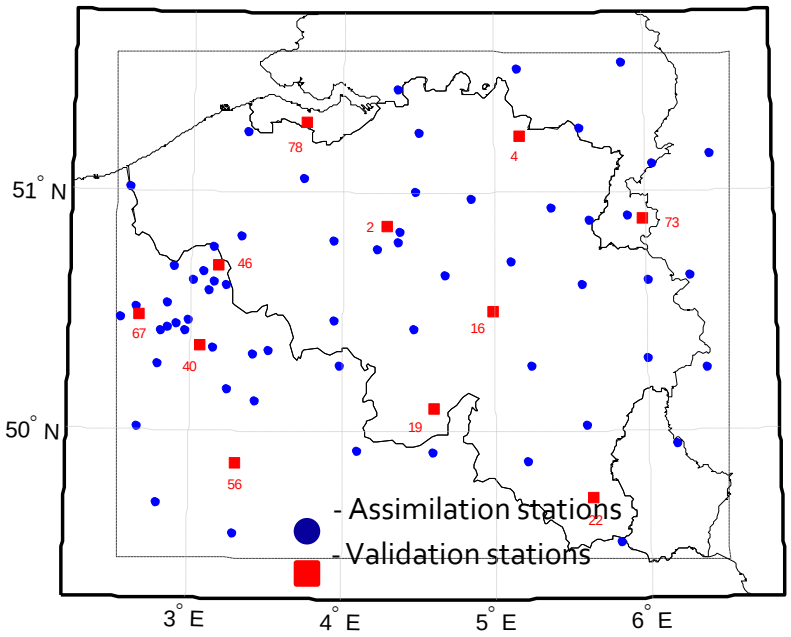
AI enabled Decision Support Systems

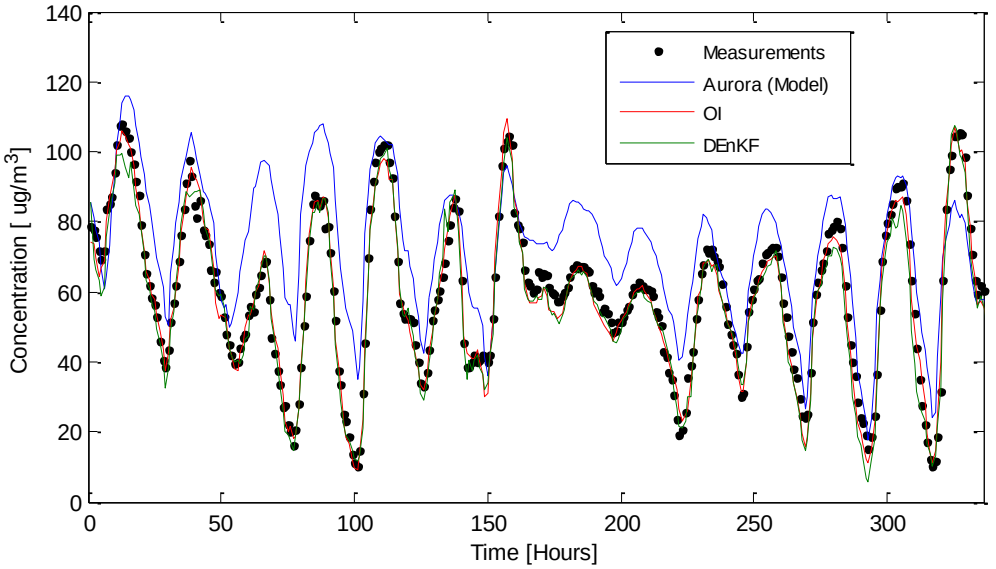
- Smart Cities DSS
  - Environmental DSS: O3 and small particles
  - Regional flood regulation DSS
  - Nationwide electrical load DSS
  - Security monitoring DSS
  - Sports DSS
- Industry 4.0 DSS
  - Chemical processes DSS
  - Mechanical structure monitoring DSS
  - Fraud detection DSS
- Mobility
  - Traffic DSS
- Precision Medicine
  - DSS for patients, professionals, policy makers
  - CDSS Ovarian Cancer, Biomarker detection
  - CDSS Monitoring Glycemia, vital signals (brain, epilepsy,…)
  - DSS Food
  - DSS Fall detection

Flanders O3/fine particle DSS

O_3 air-quality stations

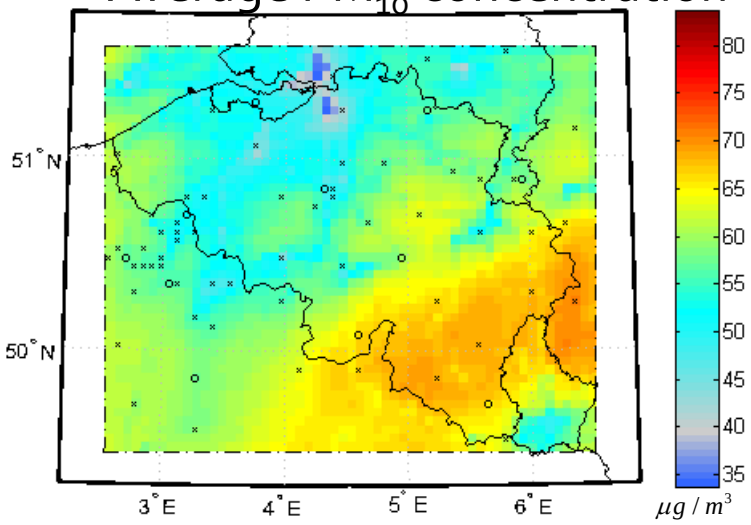


Average of the O_3 concentration over the validation stations

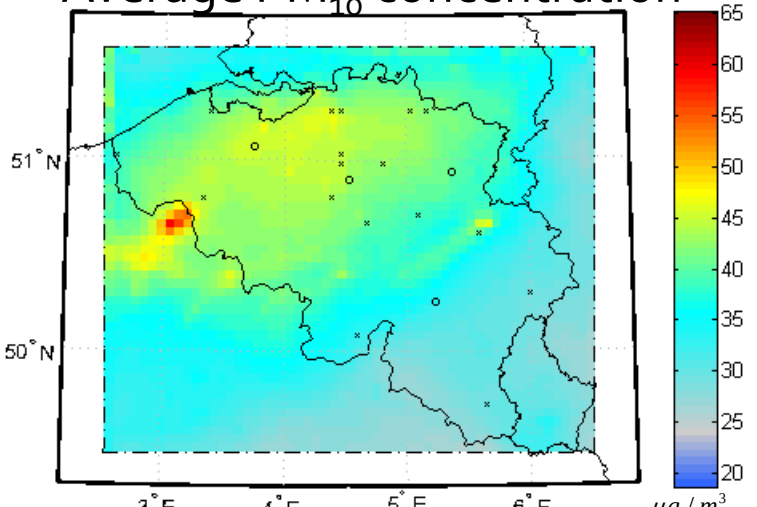


Starting date: May 28th, 2005 at midnight

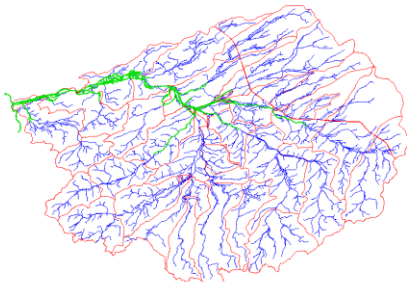
Average PM_{10} concentration

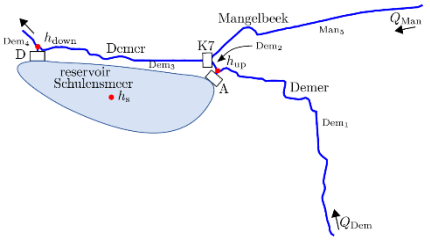


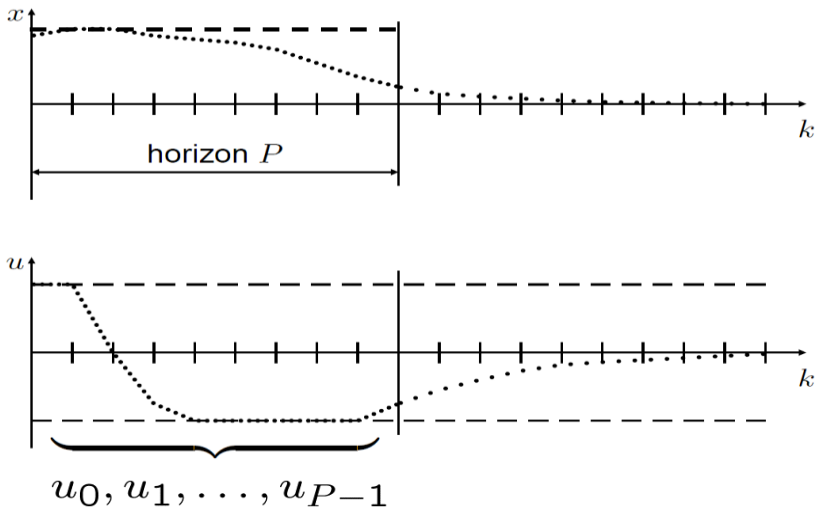
Average PM_{10} concentration



Demer Flood Regulation DSS







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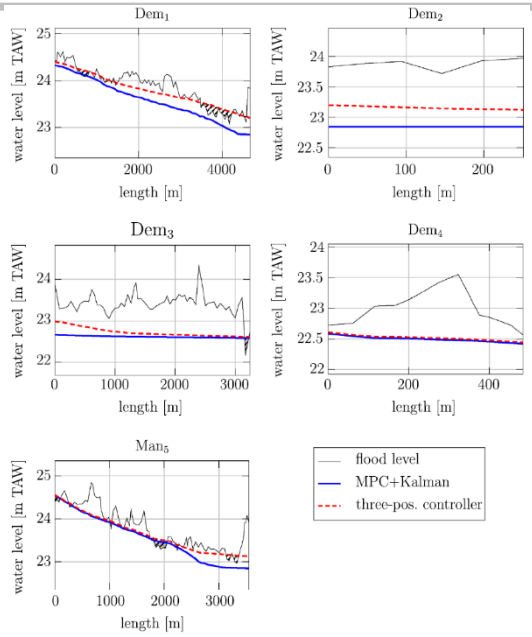
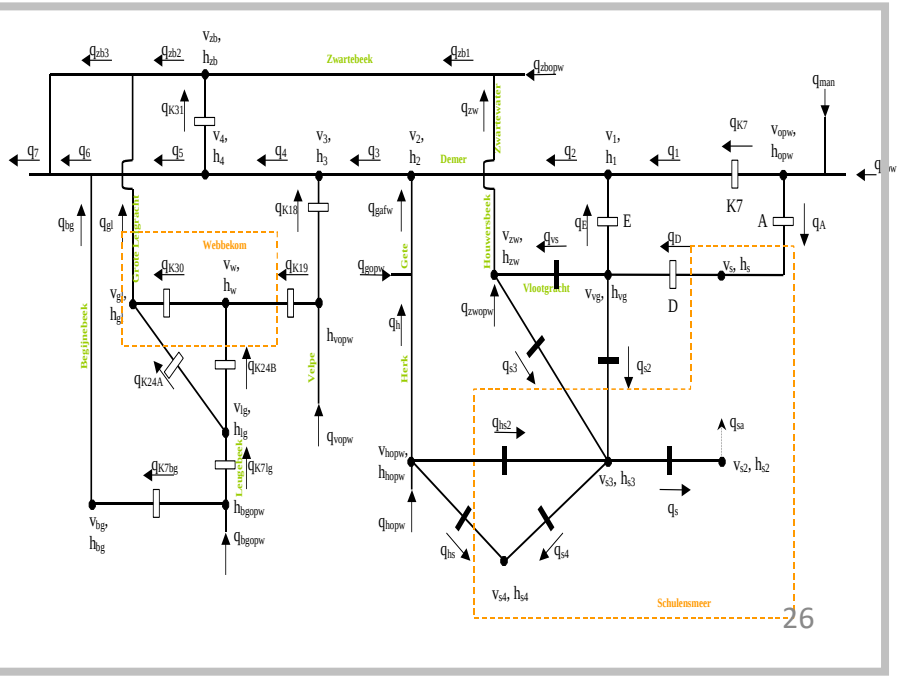
IMDC
International Marine & Dredging Consultants

IPCOS

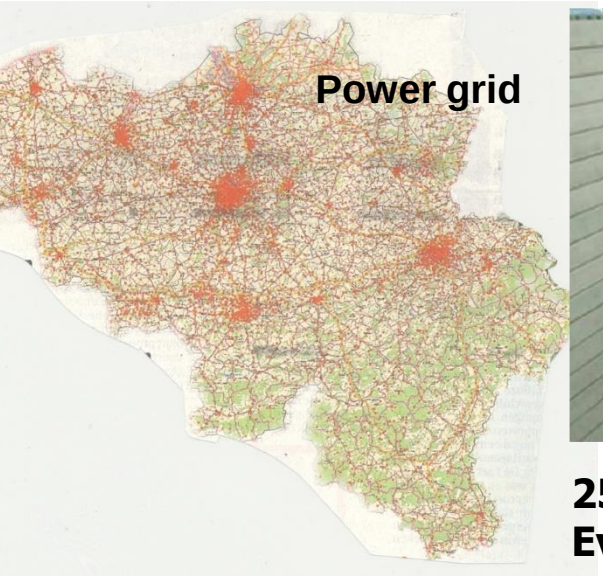
COFELY FABRICOM
GDF SUEZ

anteagroup

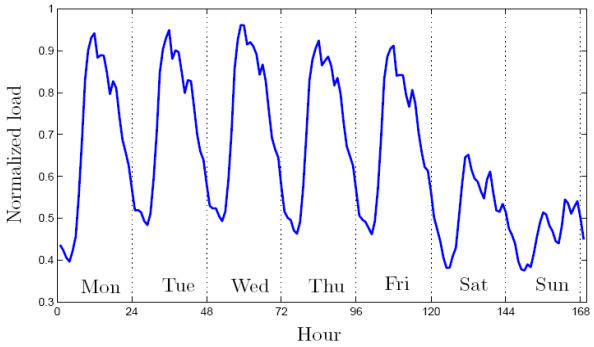




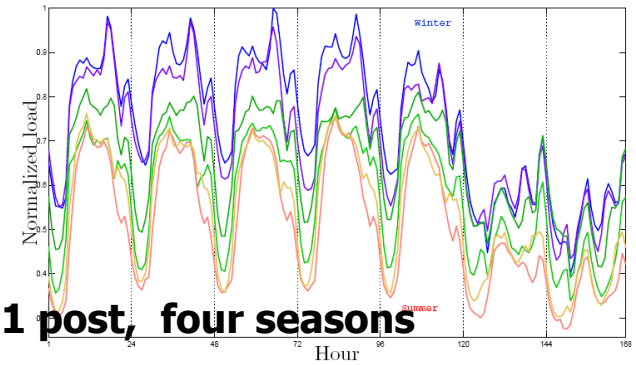
Belgian smart electricity grid DSS



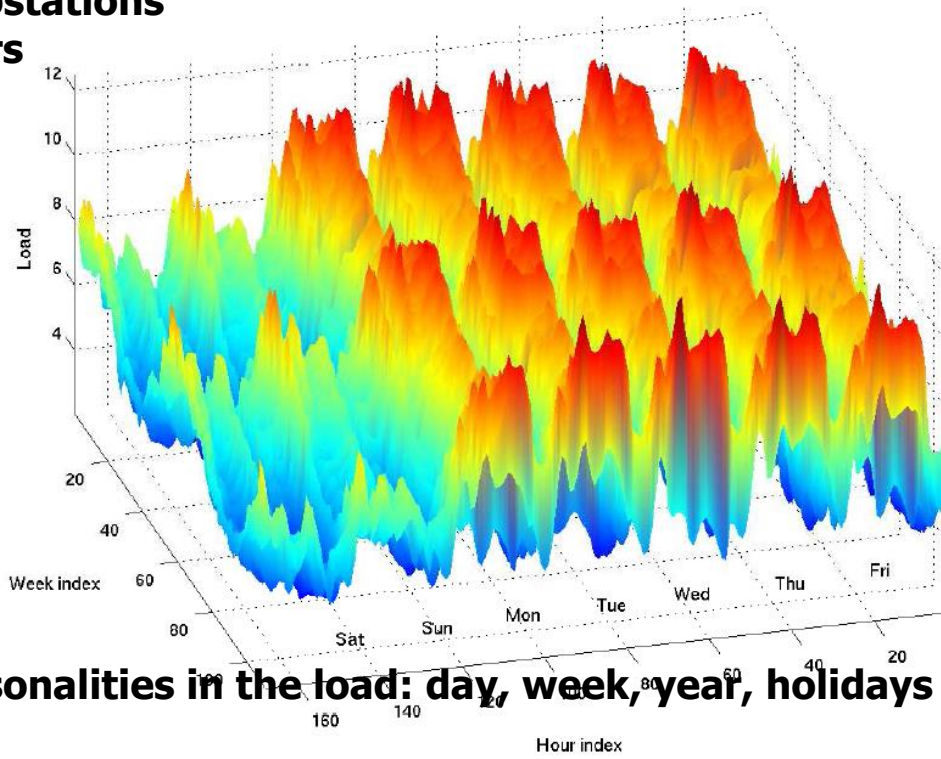
250 transformer substations
Every 15 min, 5 years



1 post, 1 week



1 post, four seasons



Seasonalities in the load: day, week, year, holidays

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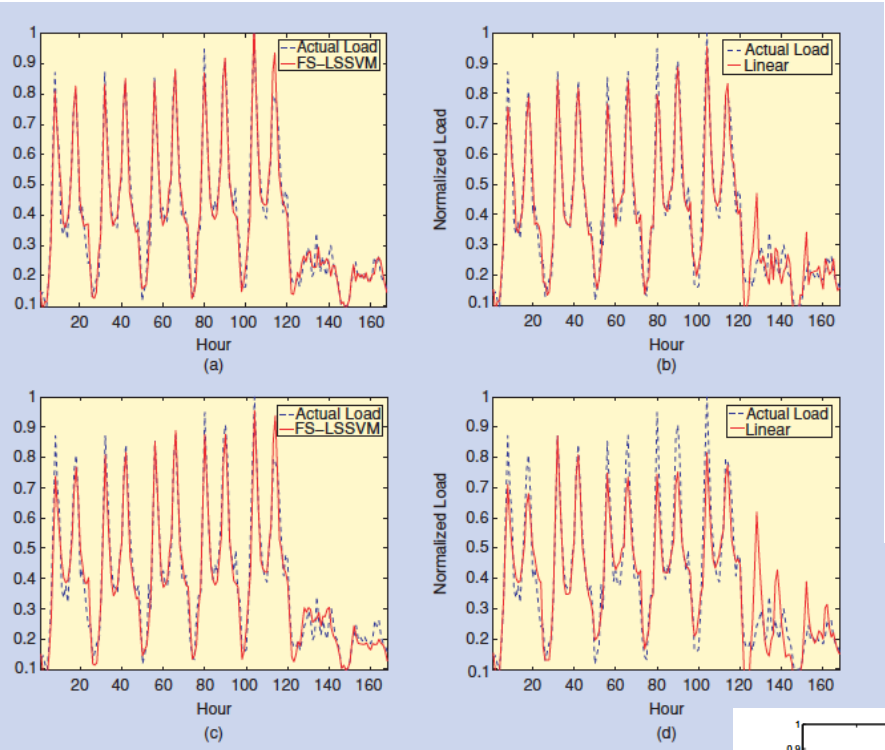
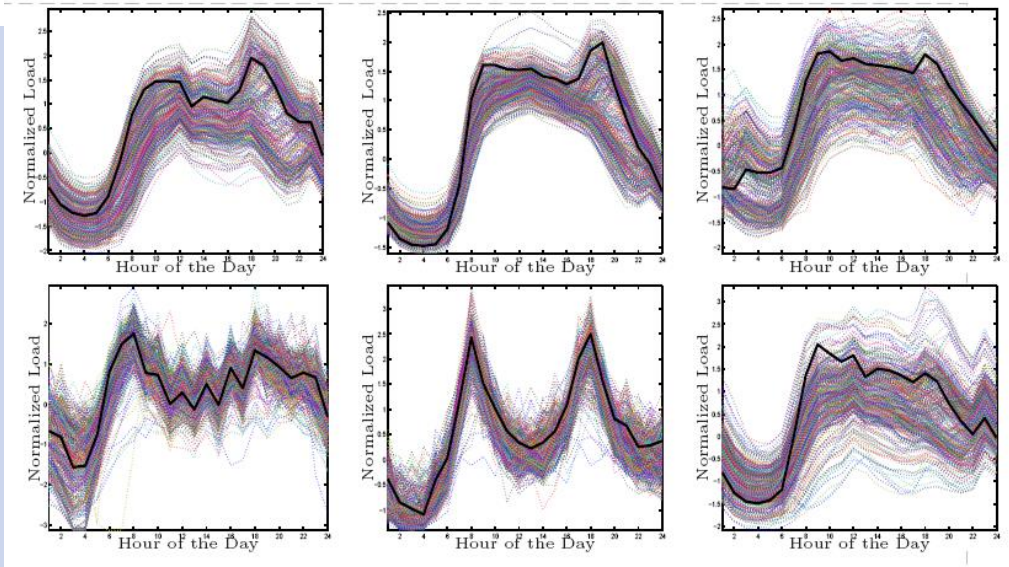
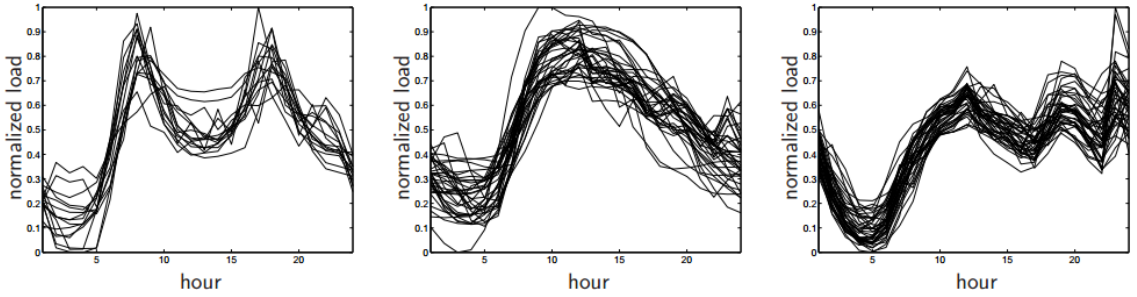




6 posts, 1 year
Seasonalities, calender holidays !

1 month predictions
depending
on day, season
and weather prediction



Electricity load: 245 substations in Belgian grid (1/2 train, 1/2 validation)
$x_i \in \mathbb{R}^{43.824}$: spectral clustering on **high dimensional data** (5 years)

3 of 7 detected clusters:
- *1: Residential profile: morning and evening peaks*
- *2: Business profile: peaked around noon*
- *3: Industrial profile: increasing morning, oscillating afternoon and evening*

Customer profiling:
Residential, business, industrial

Security monitoring DSS

Background detection

Goals:

- traffic flow monitoring and control
- security CCTV
- face recognition
- recommendation systems
  (Netflix problem)
- big data processing

Example:
Separate background and foreground objects in a sequence of frames to count, identify, analyze objects on the scene.

Challenges:

- handle **very large scale** problems
  (e.g.: 10 sec, 25 FPS, small resolution (640x480): **150M variables)**
- minimize number of iterations, which are **extremely** costly

Sport Analytics Decision Support Systems

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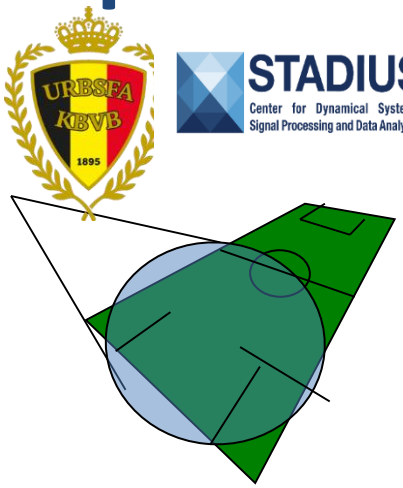
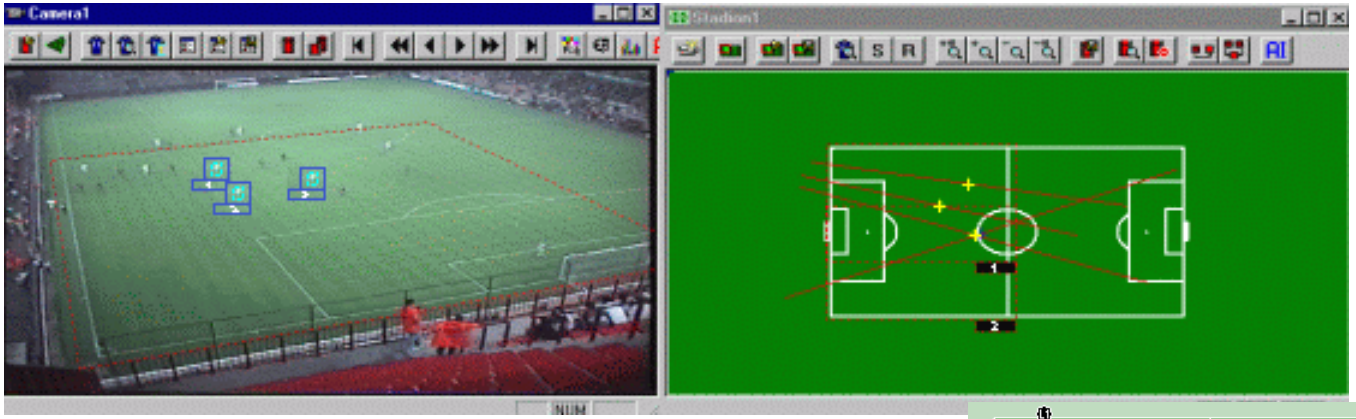
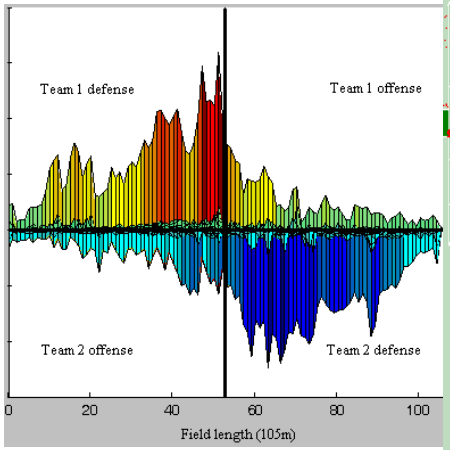
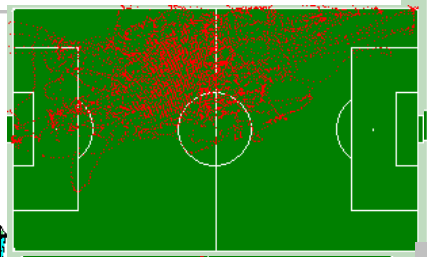
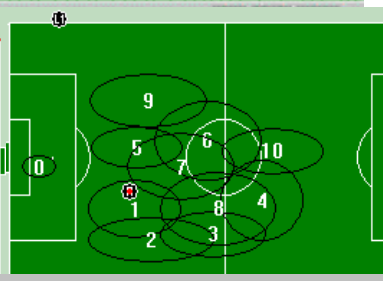


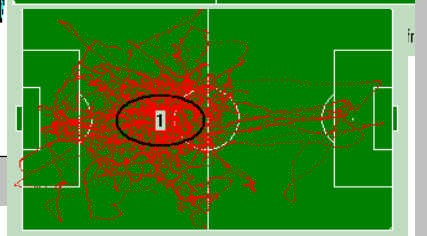


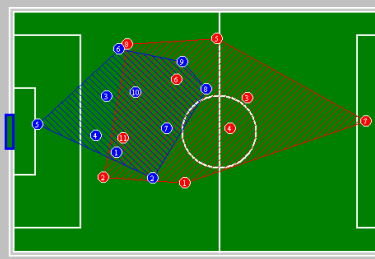
Time	Team	Action	Player	Position
0:00:00	1	Kick Off	9	(50,30)
0:00:01	1	Has Ball	10	(49,29)
0:00:04	1	Has Ball	8	(45,31)
...	...	...	...	...
0:12:25	1	Ball Out	6	(0,57)
0:12:46	2	Corner	3	(0,60)
0:12:47	2	Has Ball	4	(4,29)
0:12:49	2	Goal	4	(0,29)
0:13:38	1	Kick Off	10	(50,30)
...	...	...	...	...

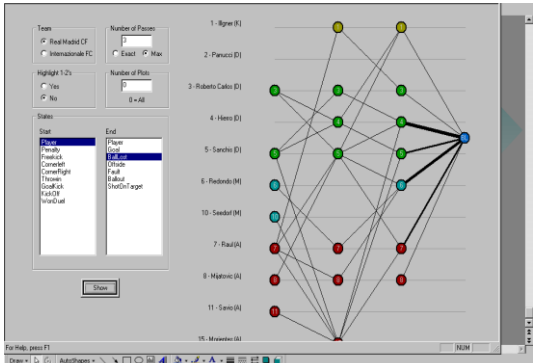


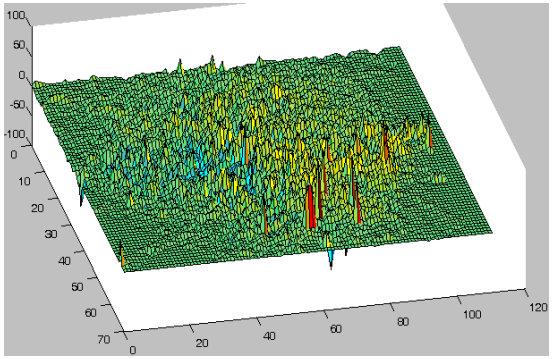


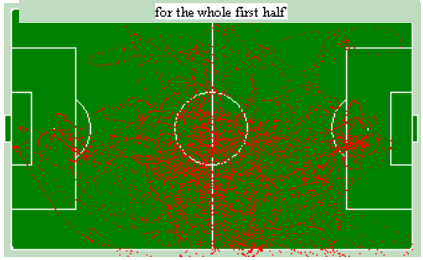


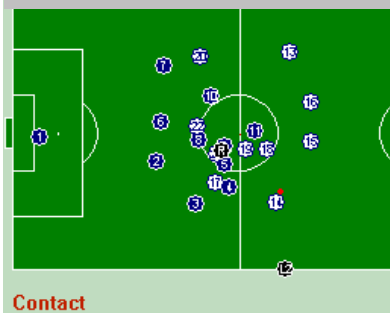












AI enabled Decision Support Systems

- Smart Cities DSS
  - Environmental DSS: O3 and small particles
  - Regional flood regulation DSS
  - Nationwide electrical load DSS
  - Security monitoring DSS
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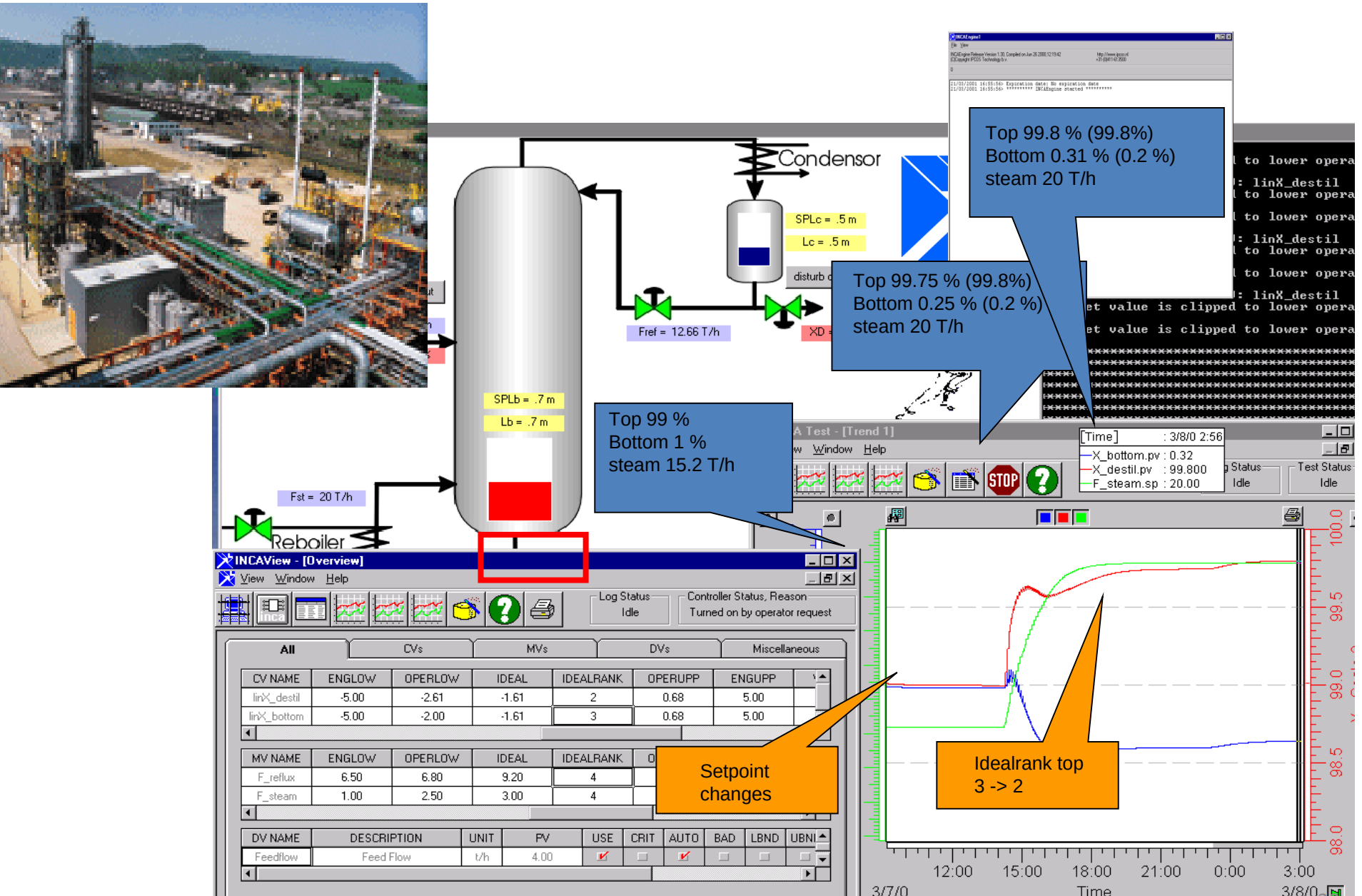
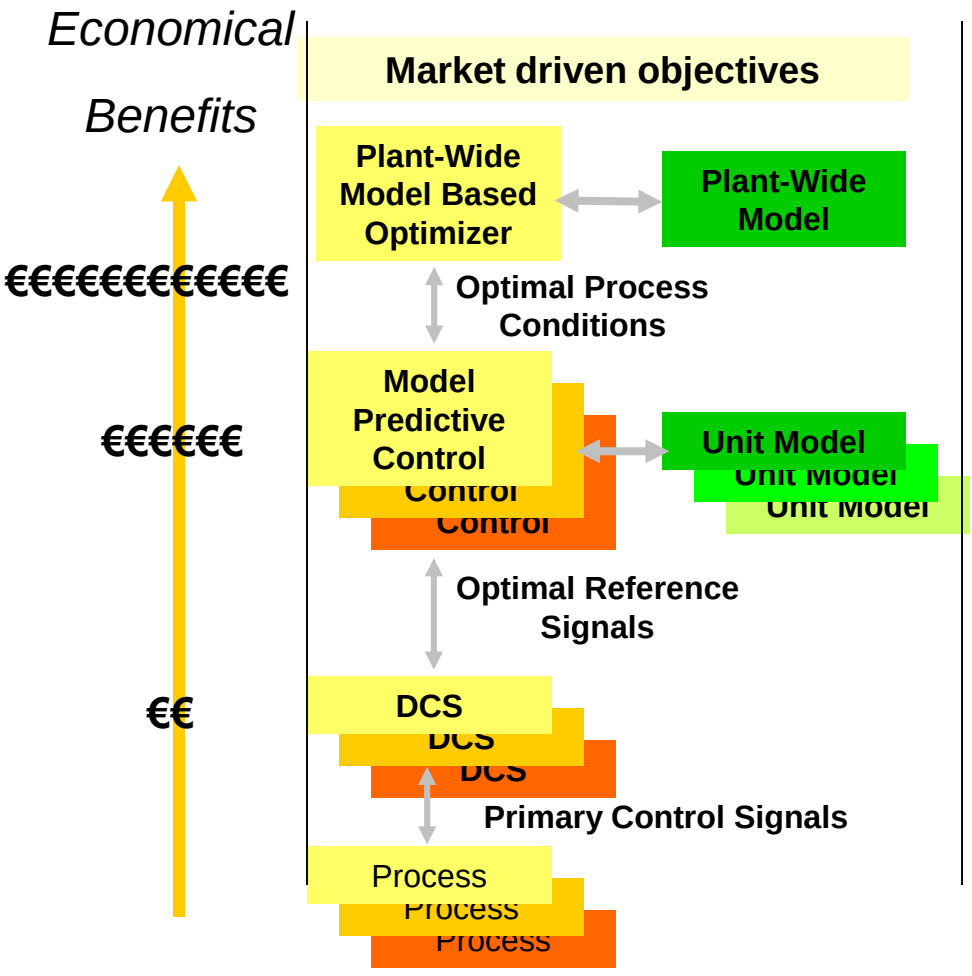
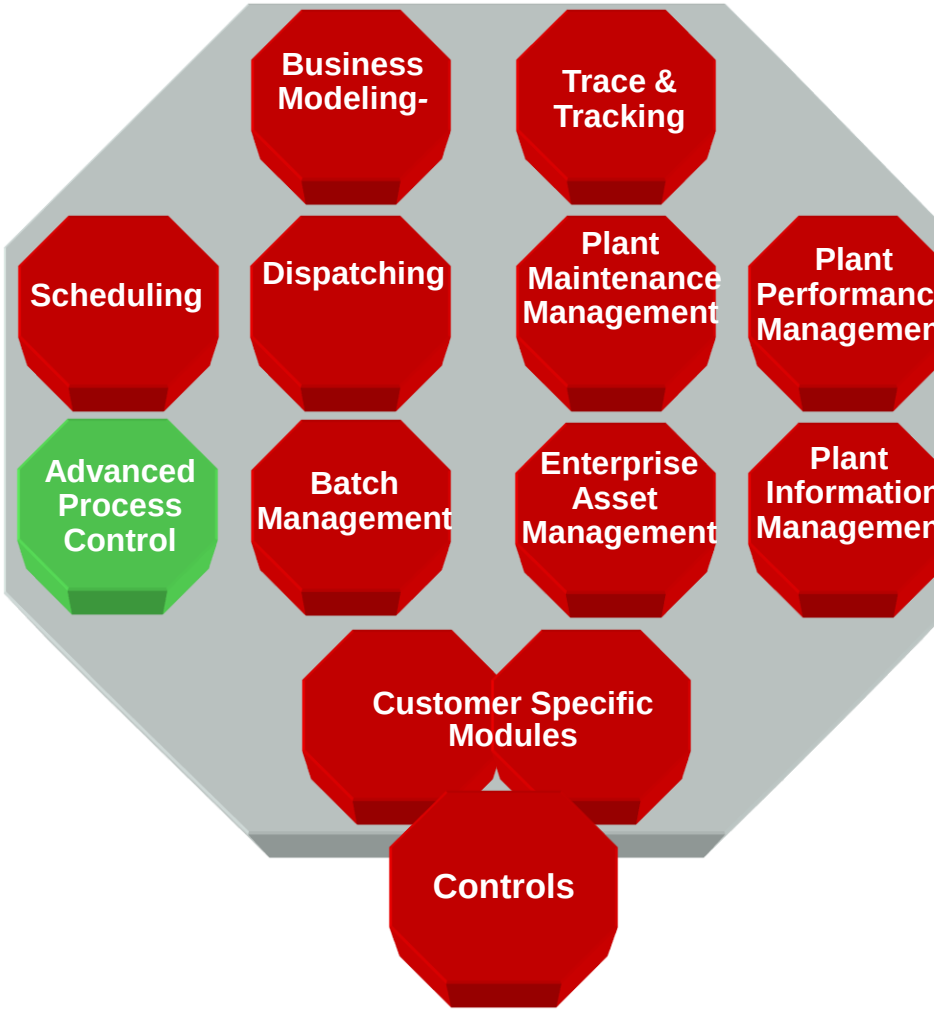
Chemical process DSS

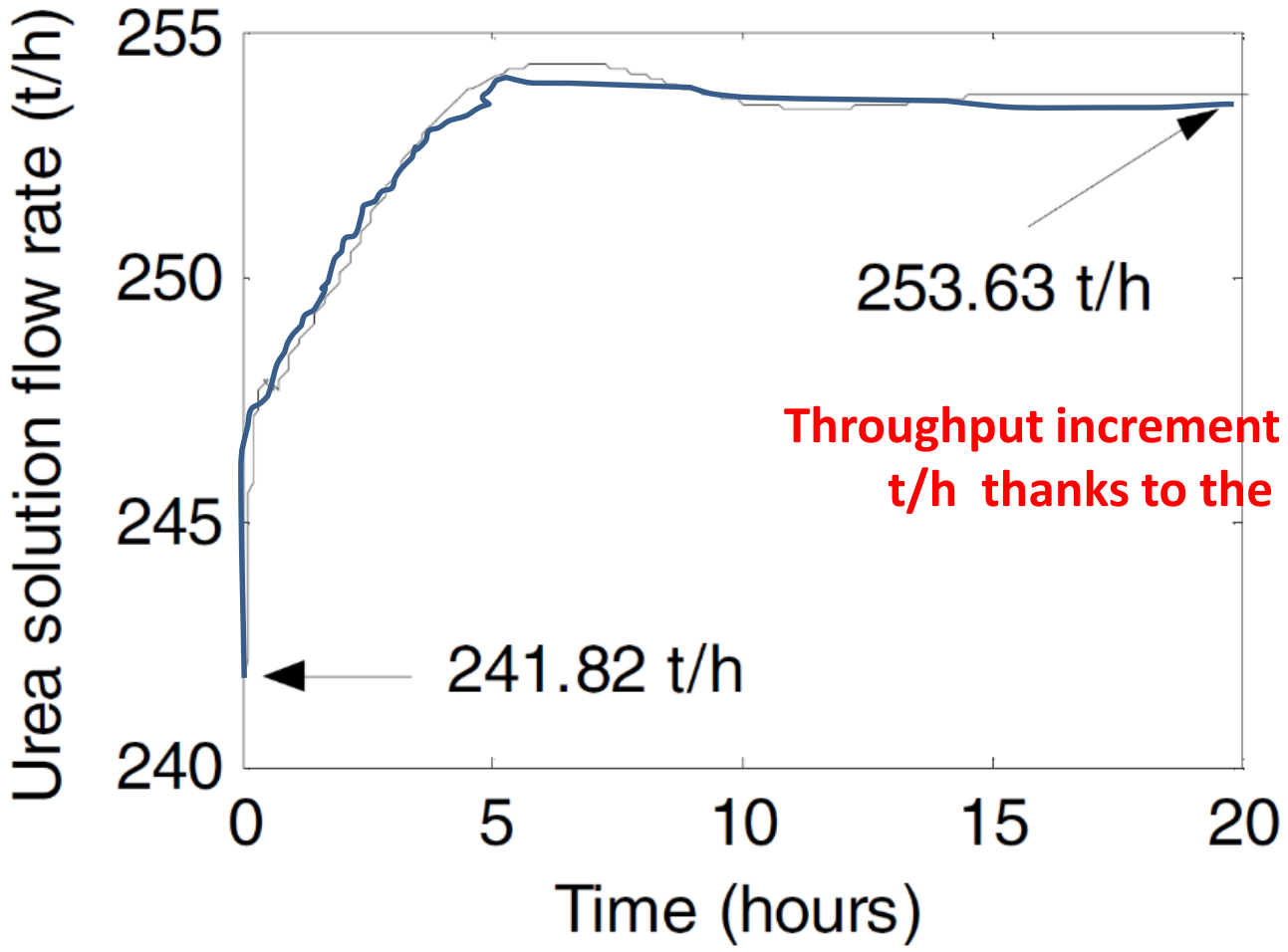


Chemical process DSS



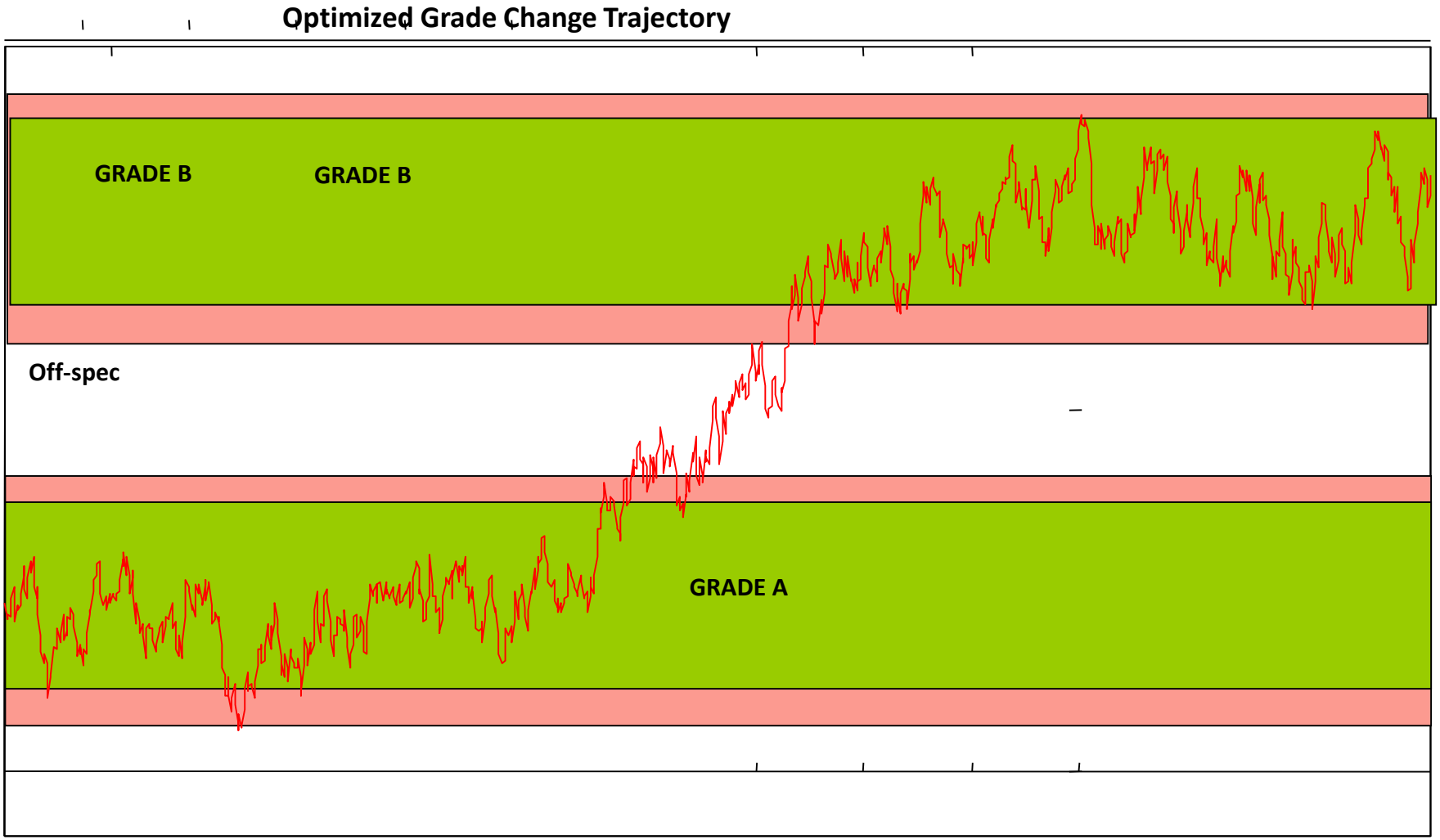


Yield optimization

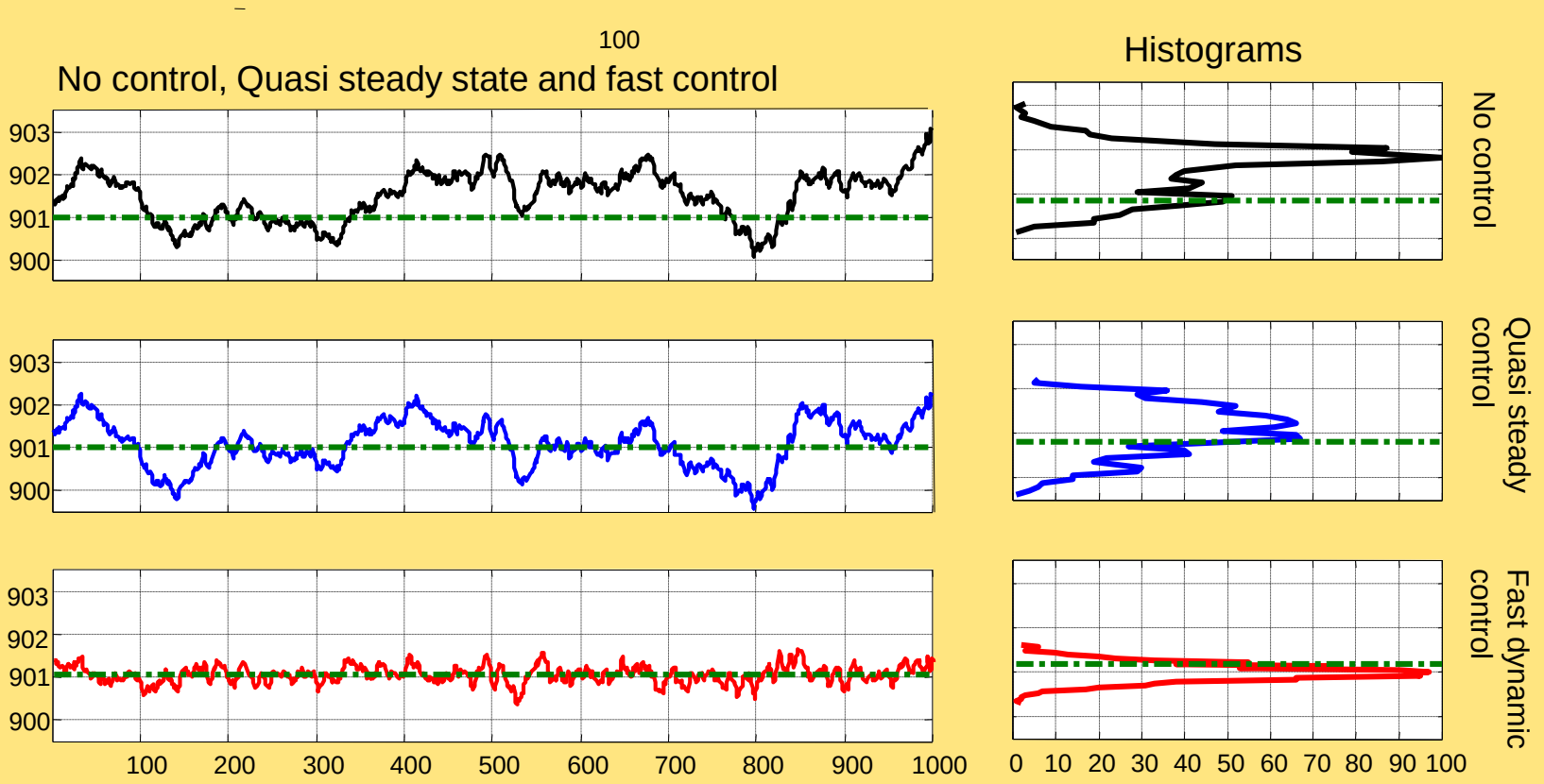


Throughput increment of 11.81 t/h thanks to the DSS

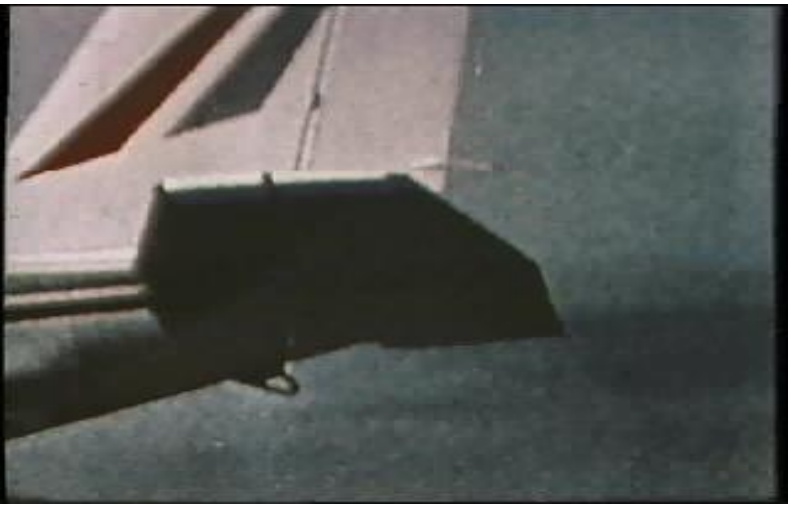
Grade transition with minimum off-spec

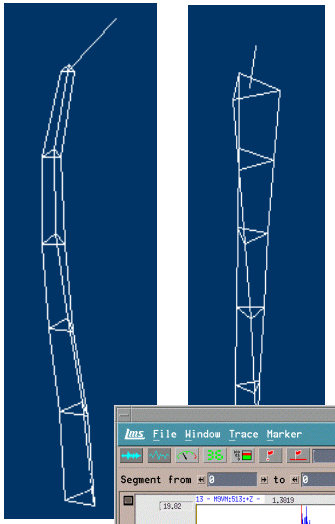


Product quality optimization



Mechanical structure monitoring DSS





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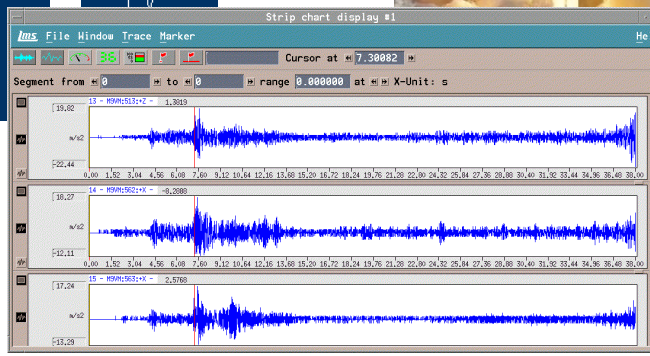
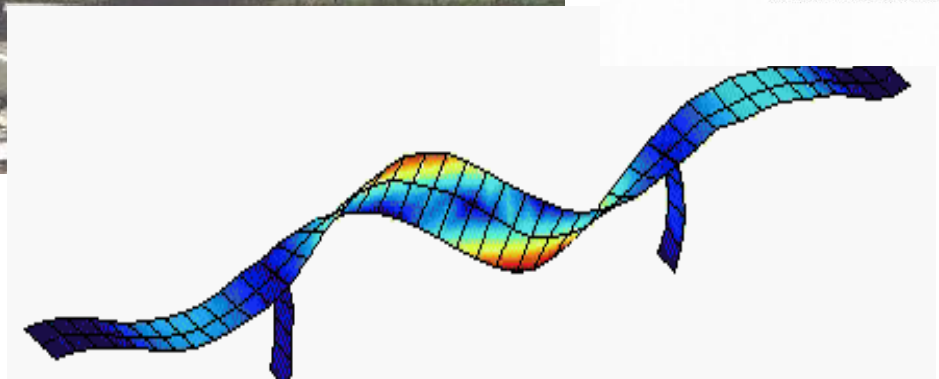
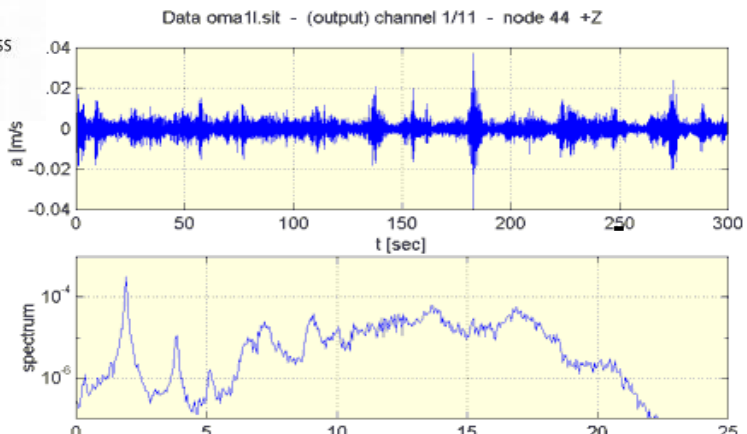


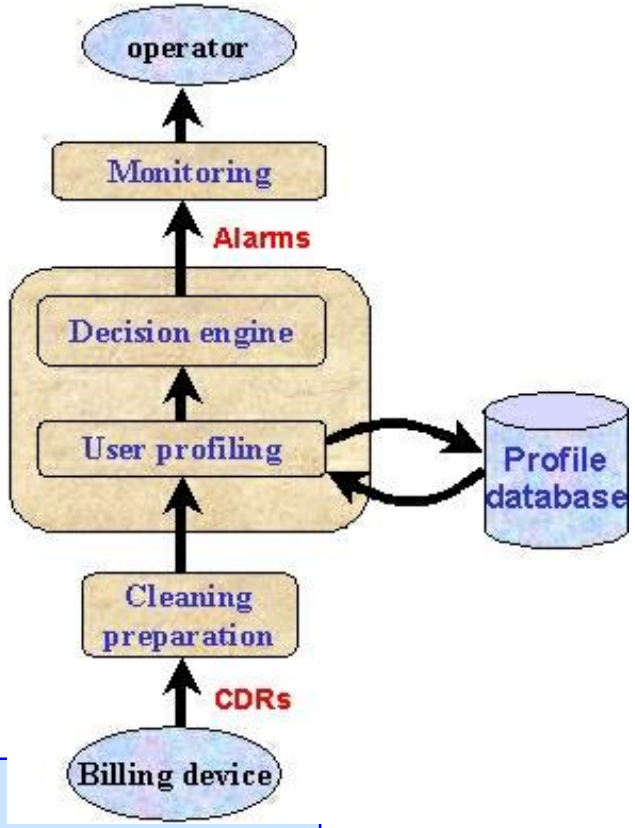
LMS®
A Siemens Business



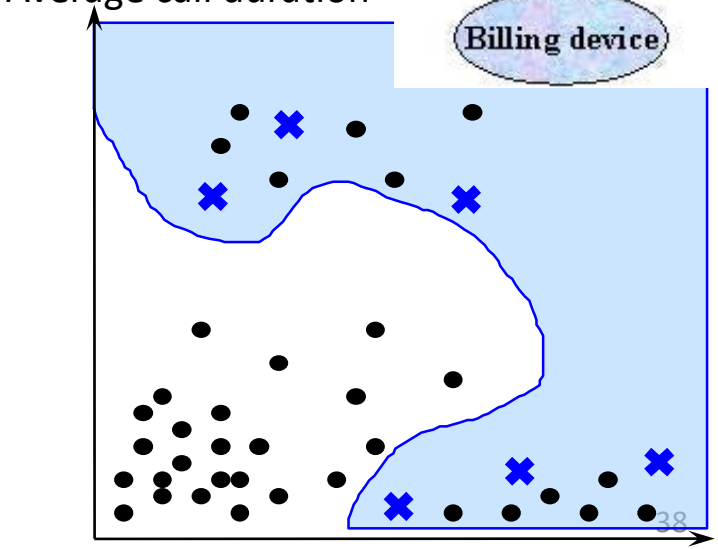


Fraud Detection DSS (phones, credit cards, tax declaration,…)

	Short Duration	Long Duration	High Frequency	International	Same Destination	Off Peak	Call Forwarding	Behaviour Change
Direct call selling		X	X	X			X	
PABX fraud	X		X		X	X		X
Freephone fraud	X		X		X			X
Premium rate fraud		X	X		X			X
Subscription fraud			X					
Handset theft		X	X	X	X			X



TAXonWEB



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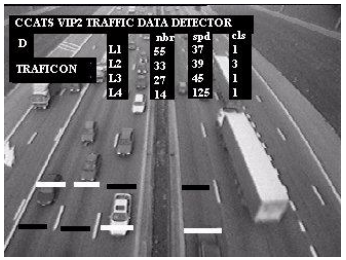
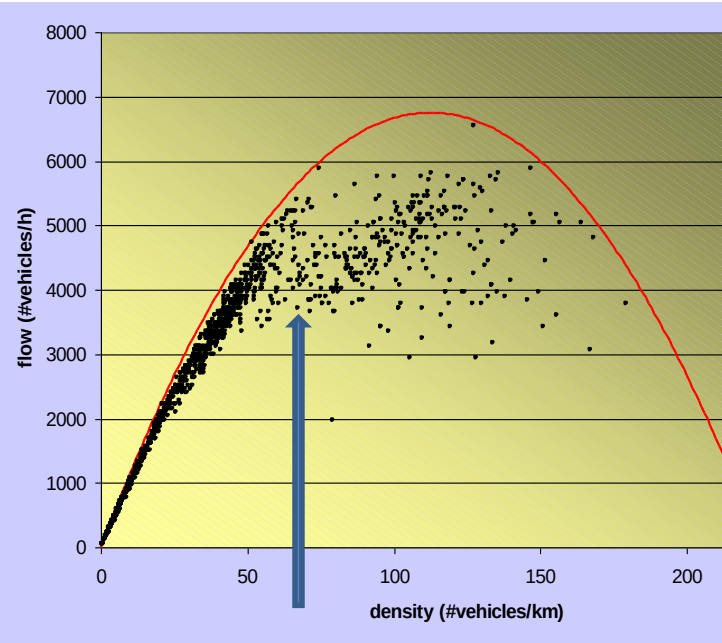
Traffic & Mobility DSS

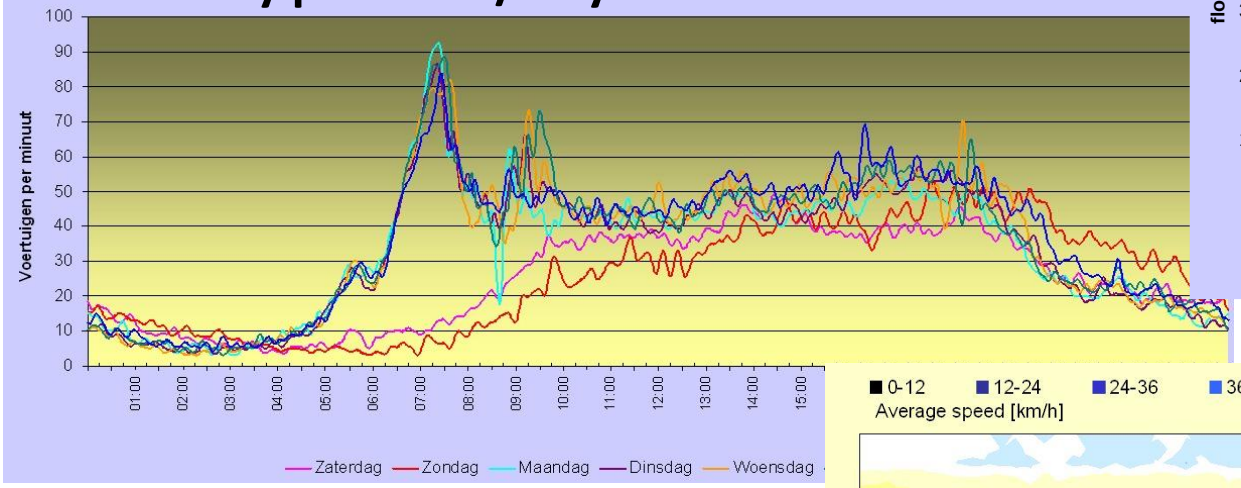
Detector technology: inductive loops, Gatso-meters, camera's



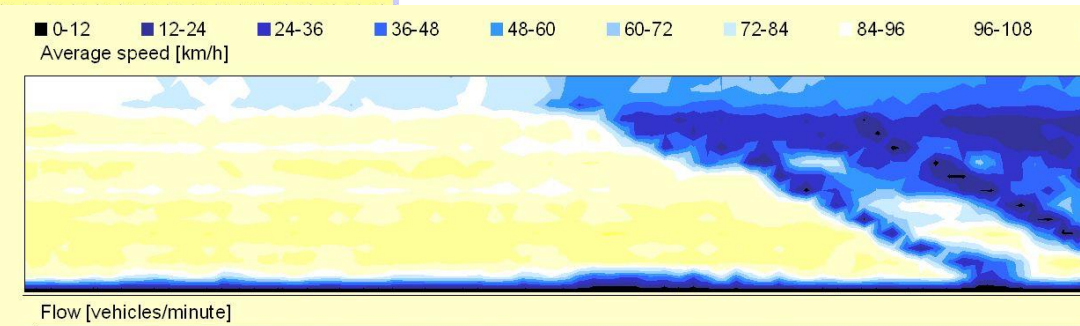
Density – Flow

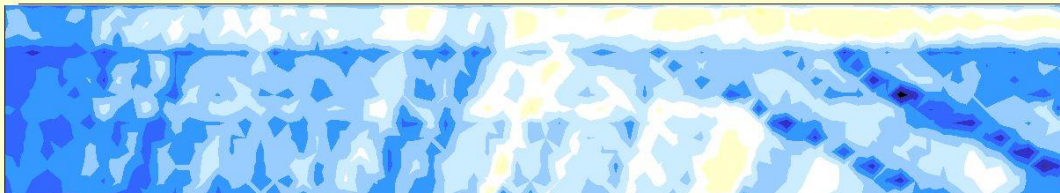


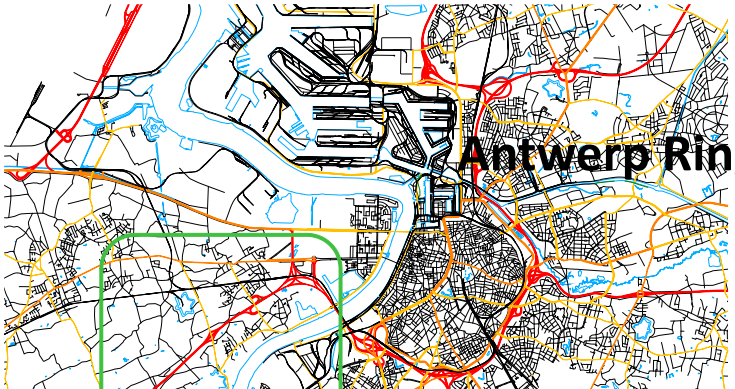
Density per hour / day of the week



Traffic jam prediction

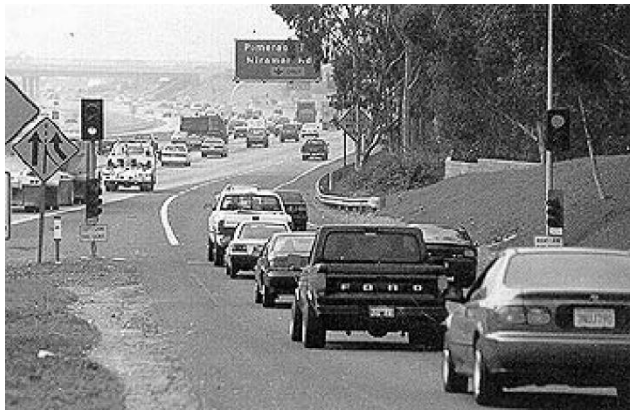






Traffic & Mobility DSS: control

Speed harmonisation

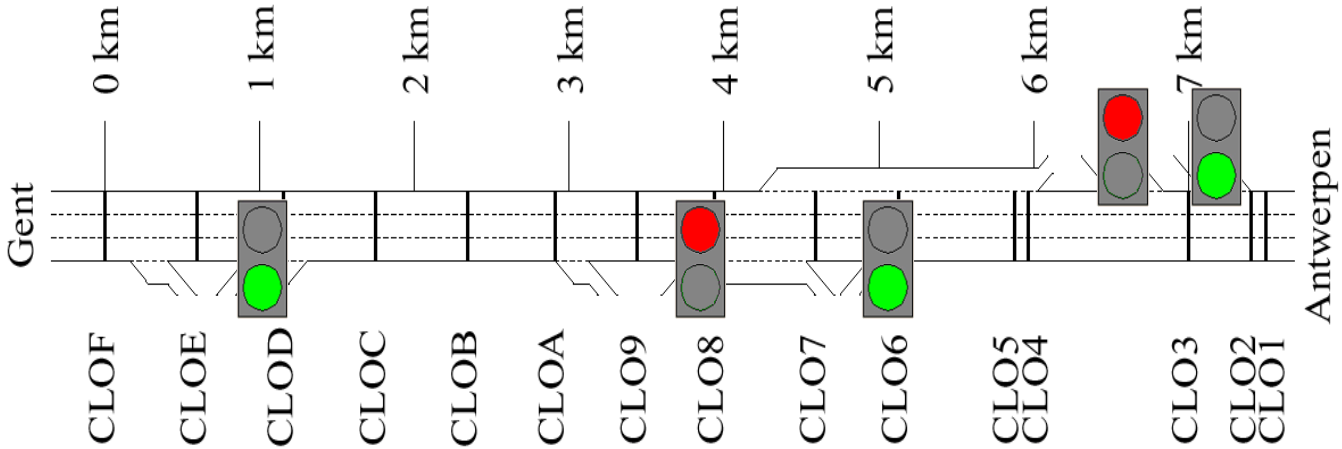


Ramp metering

DRIP

Vlaams Verkeerscentrum

Vlaamse overheid



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TRANSPORT & MOBILITY LEUVEN

AI enabled Decision Support Systems

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WHO IS IN DEMAND?

PATIENTS

POLICY MAKERS

PROFESSIONALS

IF WE CARE ABOUT THE FUTURE OF CARE…

- PATIENT HEALTH RECORD
- HEALTH DATA ANALYTICS
- TELEMEDICINE & -MONTORING
- WEARABLES & MHEALTH
- …OMICS (genomic, proteomics, metabolomics, interactomics,…)
- DECISION SUPPORT SYSTEMS

… AI WILL BE KEY

4 P's OF MEDICINE

Personalized

Customized diagnosis and treatment

Preventive

Better than curation

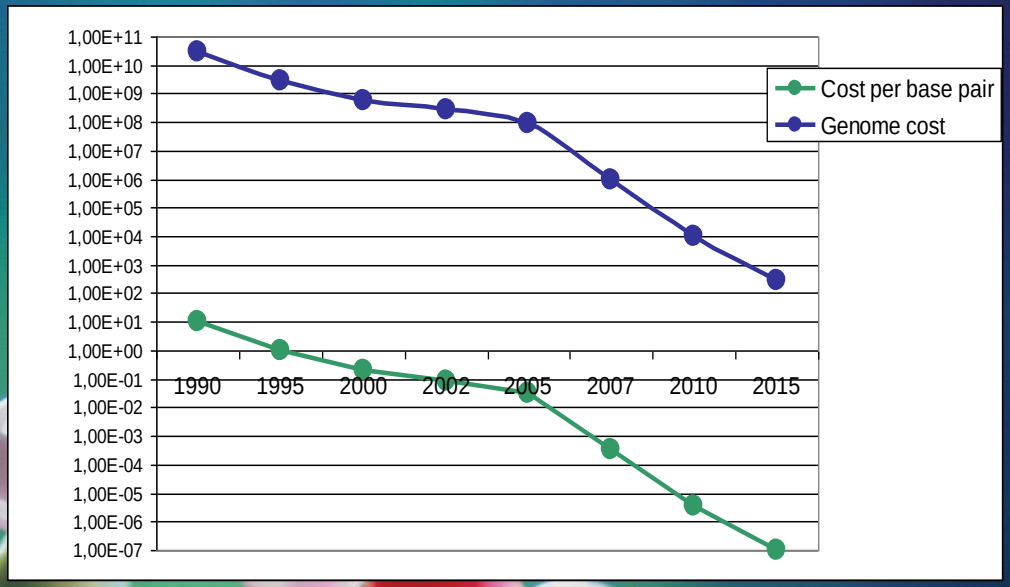
Predictive

Determine risk profiles & predict outcome

Participative

Involve the patient

Genome data



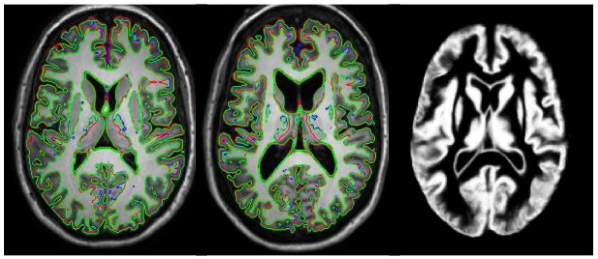
- Human genome project
  - Initial draft: June 2000
  - Final draft: April 2003
  - 13 year project
  - $300 million value with 2002 technology
- Personal genome
  - June 1, 2007
  - Genome of James Watson, co-discoverer of DNA double helix, is sequenced
    - $1.000.000
    - Two months
- €1000-genome
  - Expected 2012-2020

YearΩ	Cost per base pair	Genome cost
1990	10	3E+10
1995	1	3.000.000.000
2000	0.2	600.000.000
2002	0.09	270.000.000
2005	0.03	90.000.000
2007	0.000333333	1.000.000
2010	3.33333E-06	10000
2015	0.0000001	300

Data tsunami

Computer Tomography

Magnetic resonance

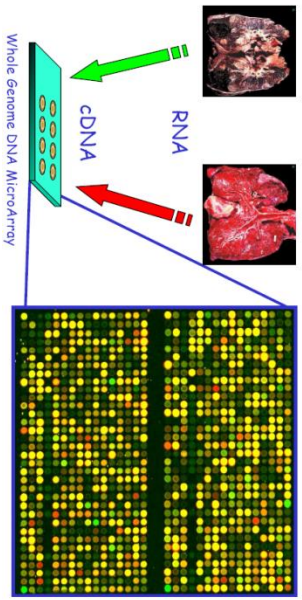


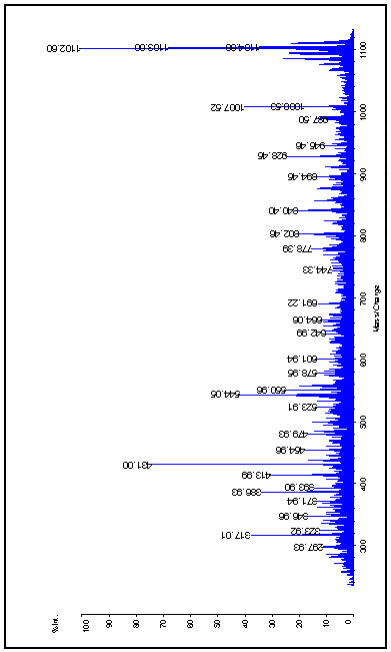
GS-FLX Roche
Applied Science 454

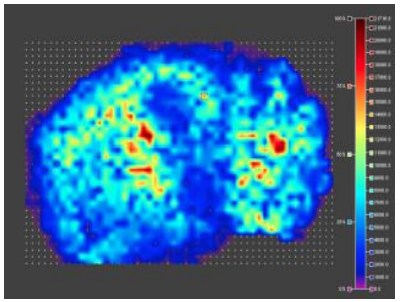
Sequencers

ACACATTAAATCTTATATGCT
AAAACTAGGTCTCGTTTTAGG
GATGTTTATAACCATCTTTGA
GATTATTGATGCATGGTTATT
GGTTAGAAAAAATATACGCTT
GTTTTTCTTTCCTAGGTTGAT
TGACTCATACATGTGTTTCAT
TGAGGAAGGAACTTAACAAAA
CTGCACTTTTTTCAACGTCAC
AGCTACTTTAAAAGTGATCAA
AGTATATCAAGAAAGCTTAAT
ATAAAGACATTTGTTTCAAGG
TTTCGTAAGTGCACAATATCA
AGAAGACAAAAATGACTAATT
TTGTTTTCAGGAAGCATATAT
ATTACACGAACACAAATCTAT
TTTTGTAATCAACACCGACCA
TGGTTCGATTACACACATTAA
ATCTTATATGCTAAAACTAGG
TCTCGTTTTAGGGATGTTTAT
AACCATCTTTGAGATTATTGA
TGCATGGTTATTGGTTAGAAA
AAATATACGCTTGTTTTTCTT
TCCTAGGTTGATTGA

Microarrays
(DNA chips)

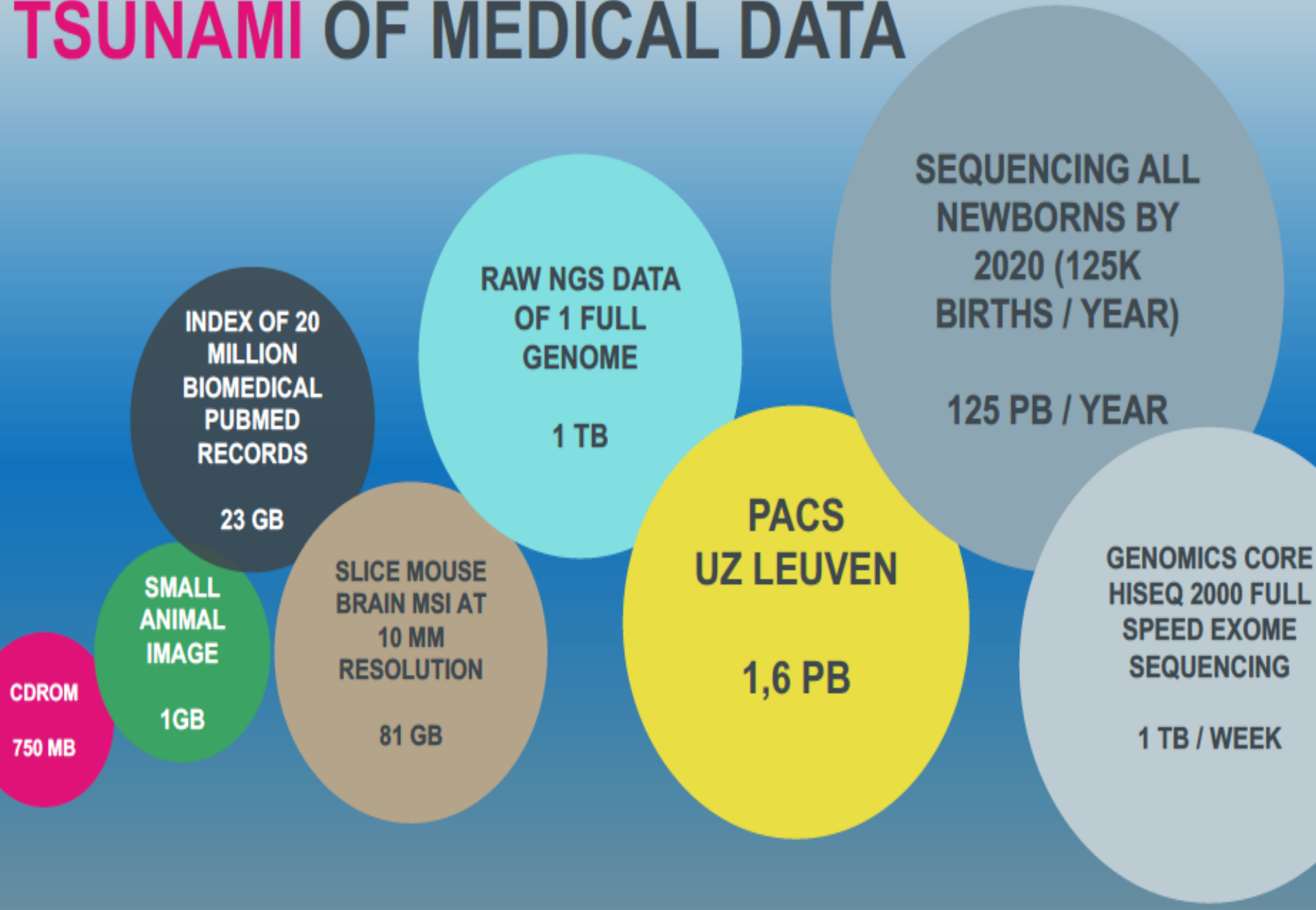






Mass spectrometry

TSUNAMI OF MEDICAL DATA



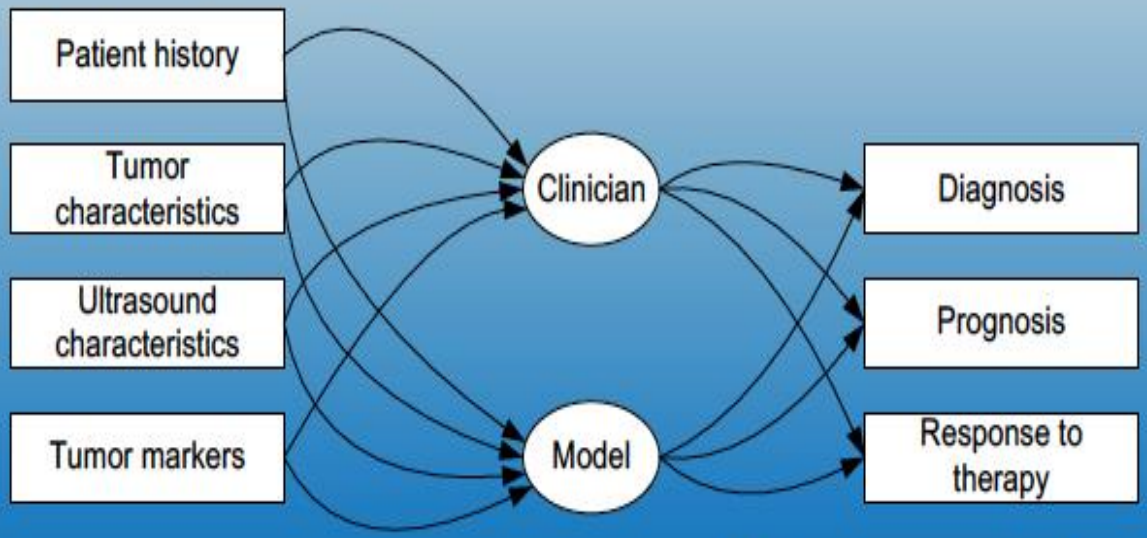
Dr. Algorithm is coming

"In the next 10 years, data science and software will do more for medicine than all the biological sciences together."

– Vinod Khosla, Khosla Ventures

http://techcrunch.com/2013/09/11/vinod-khosla-in-the-next-10-years-dat
science-will-do-more-for-medicine-than-all-biological-sciences-combine

Example: CDSS Ovarian Cancer



standardize ultrasonographic ovarian tumor analysis → models giving an indication of the probability of malignancy of an ovarian tumour based on 6 to 12 observed parameters

IOTA app to assess ovarian tumour malignancy: population based / standardized

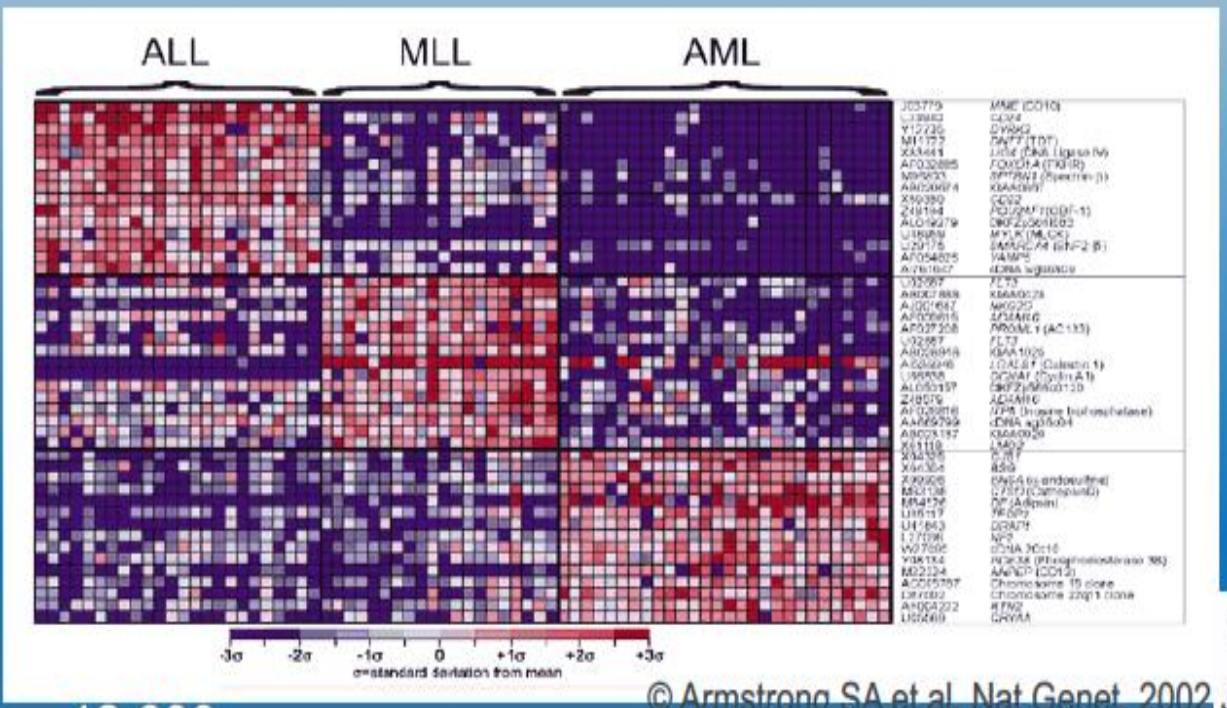
IOTA 2013
International Ovarian Tumour Analysis

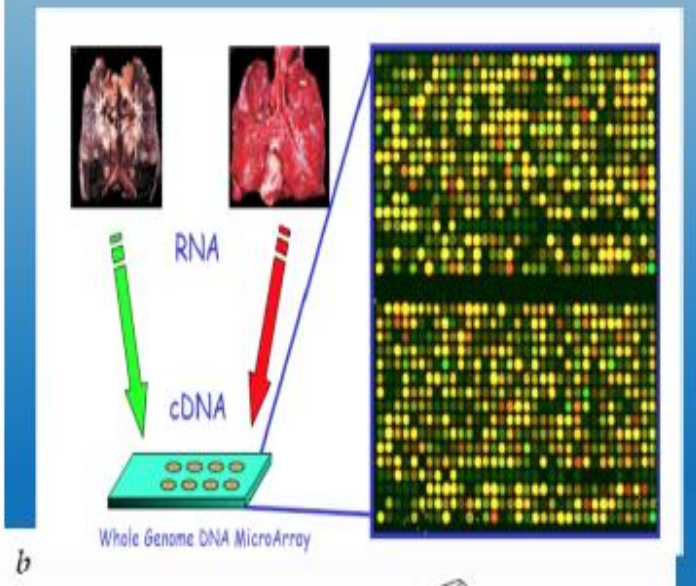
General challenges & opportunities

- Integration of various heterogeneous data sources
- Connect with Electronic Medical Records
- Need for population data

IOTA app available in iTunes app store and on http://homes.esat.kuleuven.be/~sistawww/biomed/iota/

Example: Genomic markers for Leukemia



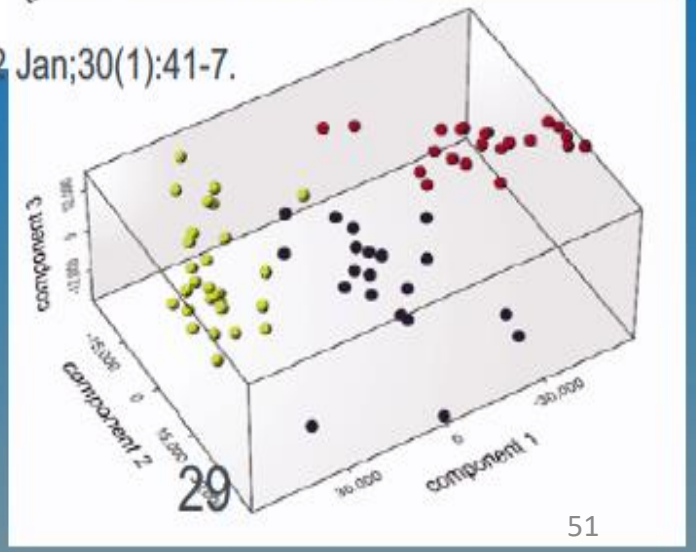


© Armstrong SA et al. Nat Genet. 2002 Jan;30(1):41-7.

12 600 genes

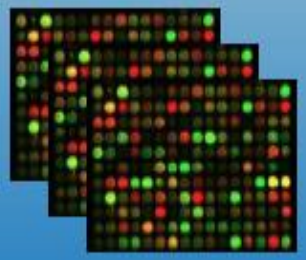
72 patients

- 28 Acute Lymphoblastic Leukemia (ALL)
- 24 Acute Myeloid Leukemia (AML)
- 20 Mixed Linkage Leukemia (MLL)

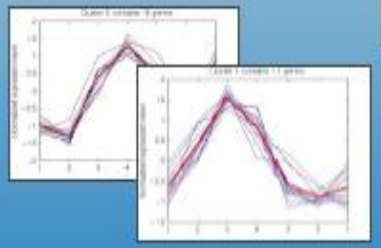


Example: Genomic Data Fusion

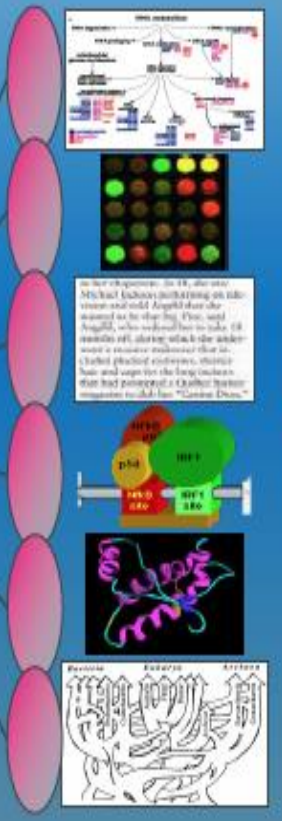
High-throughput genomics



Data analysis



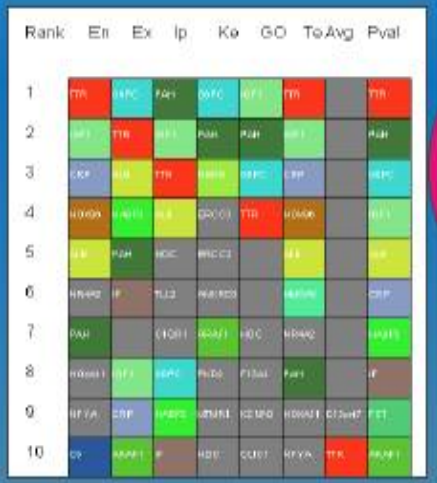
Information sources



Candidate genes

Name	Ensembl
TTR	ENSG00000118271
PAH	ENSG00000171759
G6PC	ENSG00000131482
IGF1	ENSG00000017427
ALB	ENSG00000163631
CRP	ENSG00000132693
HABP2	ENSG00000148702
IF	ENSG00000138799
FST	ENSG00000134363
ARAF1	ENSG00000078061
HMGA2	ENSG00000149948
C9	ENSG00000113600
PCBP3	ENSG00000111405
HOXB6	ENSG00000108511
RERE	ENSG00000142599
HOXA11	ENSG00000005073
CLIC1	ENSG00000099238
ERCC3	ENSG00000163161
ERCC3	ENSG00000163161
TLL2	ENSG00000095587
SYT4	ENSG00000132672
SYT4	ENSG00000132672
PIK4CB	ENSG00000143393
PKD2	ENSG00000118762
	ENSG00000081026
ANKRD3	ENSG00000183421
F13A1	ENSG00000124491
BPAG1	ENSG00000161814
KCNN3	ENSG00000143603
GRIN2A|GRIN2B	ENSG00000160098
SIM1	ENSG00000112246
	ENSG00000174891
	ENSG00000088195
C14orf10	ENSG00000092020
STX5	ENSG00000170310
	ENSG00000107671
MSH5	ENSG00000099474
CRH	ENSG00000147571
MID1	ENSG00000101871
	ENSG00000184508
	ENSG00000113460
TGFB3	ENSG00000119699
C1QR1	ENSG00000125810
NR4A2	ENSG00000153234
PDGFC	ENSG00000145431
PDGFC	ENSG00000145431
NR3C2	ENSG00000151623
NFYA	ENSG00000001167
	ENSG00000101898
C8orf4	ENSG00000175807
TM4SF13	ENSG00000106537
MMP3|MMP1	ENSG00000149968

Candidate prioritization



Validation

Endeavour: Aerts et al., Nature Biotechnology, 2006

Example: Glycemia control in ICU

- 10 mio adult ICU patients / year (EU + US) (1-2 b$ market)
- 'Tight Glycemic Control (TGC) in intensive care unit lowers mortality'
  - implement through LOGIC-Insulin: semi-automatic control system that advises nurse on insulin dosage and blood sampling interval aiming at TGC and avoiding hypoglycemia
- LOGIC-I randomized clinical trial (single-centre): compared with expert nurses, LOGIC-Insulin showed improved efficacy of TGC without increasing rate of hypoglycemia
- LOGIC-II randomized clinical trial (multi-centre): Start February 2014

in collaboration with ICU UZ Leuven

UZ LEUVEN

Menu

- From science to technology
- The fourth paradigm
- AI waves
- Use Cases
- Government action programs

KU LEUVEN

STADIUS
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Muyters initiatief AI/CS/PM

- 60 mio €, 2019-2020-….
  - AI (30 mio €)
  - CS (20 mio €)
  - PM (10 mio €)
- AI (30 mio €)
  - Luik I: Flankerend Beleid (5 mio €)
    - Kennis-/adviescentrum Ethiek en Maatschappelijke Impact
    - Opleidingen
      - Regulier kanaal (BaMa's)
      - Additionele opleidingskader
  - Luik II: Implementatie naar industrie (13 mio €)
    - AI one stop shop
    - VLAIO instrumentarium
  - Luik III: Strategisch Basisonderzoek (12 mio €)
    - 2 a 4 programmalijnen

Menu

- From science to technology
- The fourth paradigm
- AI waves
- Use Cases
- Government action programs

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