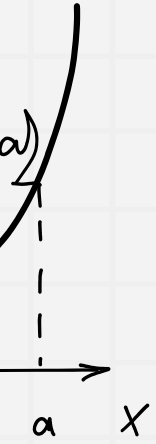
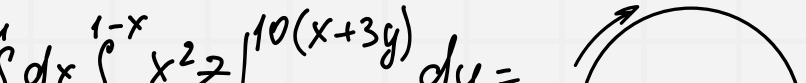
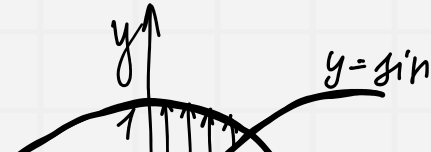
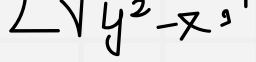
Matematika di Industri (Migas)

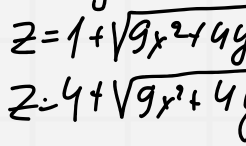
Aditya Firman Ihsan



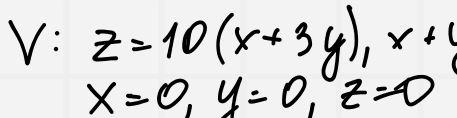


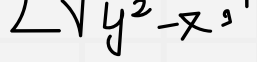


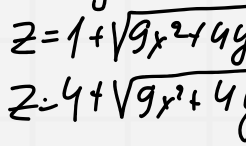




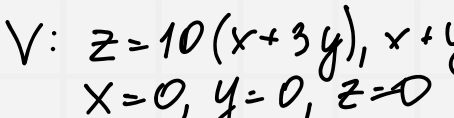
Bagaimana matematika berhubungan dengan realita?







Realita butuh representasi untuk dipahami



model *(n): a miniature representation of something; a pattern of something to be made; an example for imitation or emulation; a description or analogy used to help visualize something (e.g., an atom) that cannot be directly observed; a system of postulates, data and inferences presented as a mathematical description of an entity or state of affairs*

— Lydm, 2014

$\sum \sqrt{y^2 - x^2}$

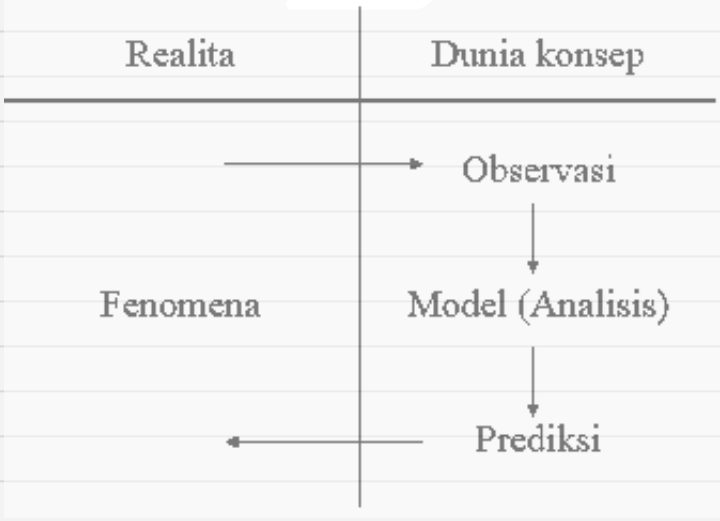
$z = 1 + \sqrt{9x^2 + 4y}$

$z = 4 + \sqrt{9x^2 + 4y}$

$\iiint$

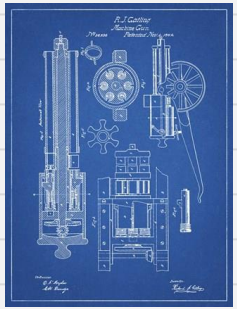
V: $z = 10(x + 3y)$, $x +$

$x = 0$, $y = 0$, $z = 0$



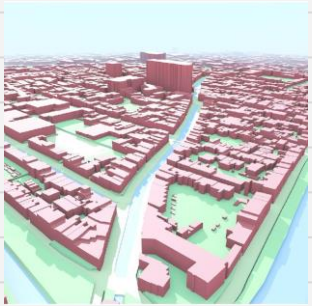
Model menjadi “potongan” realita untuk memudahkan pemahaman, insight, analisis, dll

Setiap model merupakan miniatur dari realita



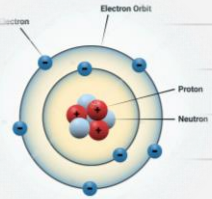
Model teknologi

Model karakter



Model kota

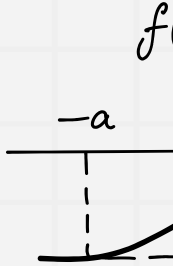
Model fashion



Model atom

$2\sqrt{y^2-x^3}$

Di sini matematika berperan



Dunia matematika adalah dunia yang bersih dari bias, eksak, rigid, tegas, dan universal.

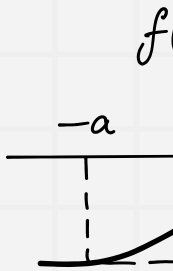
Dalam rangka mendeskripsikan realitas, model yang dibangun dengan matematika menjadi model yang lebih rigid dan universal.

$+3y)\,dy =$

$\iiint x^2\,dx\,dy\,dz =$

$2\sqrt{y^2-x^2}$

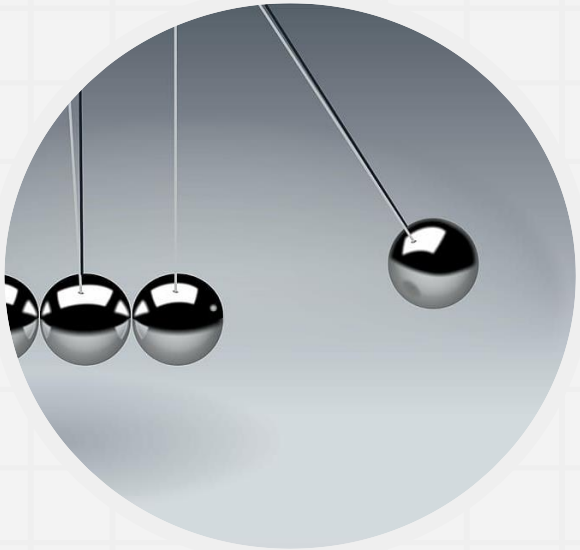
Realitas → Model konseptual → Model matematis



Untuk bisa mendapatkan representasi yang lebih rigid, objektif, dan prediktif, model-model perlu dibawa ke dunia matematis

$+3y)\,dy =$

$$\iiint x^2\,dx\,dy\,dz =$$



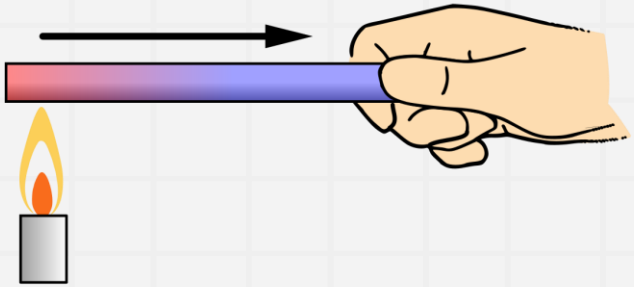
Misalkan, hukum 2 newton

Newton hanya bilang bahwa gaya yang bekerja pada benda merupakan laju perubahan dari momentumnya.

Ketika diformulasikan, menjadi

$$\Sigma F = m\frac{d^2x}{dx^2}$$

Gerak benda bisa lebih dihitung secara akurat.

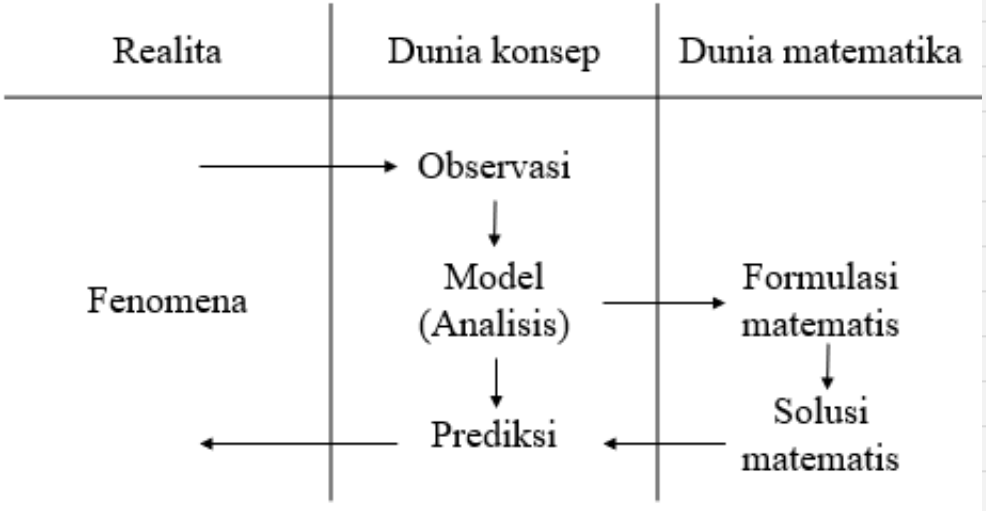


Misalkan, hukum Fick

Fick bilang bahwa panas mengalir dari tinggi ke rendah mengikuti gradien panasnya.

Hukum ini ketika diformulasikan menjadi persamaan difusi yang terkenal

$$u_t = Du_{xx}$$



Dunia matematika membawa model konseptual menjadi lebih rigid untuk diselesaikan

SAMAKAH DENGAN MODEL KOMPUTASI?

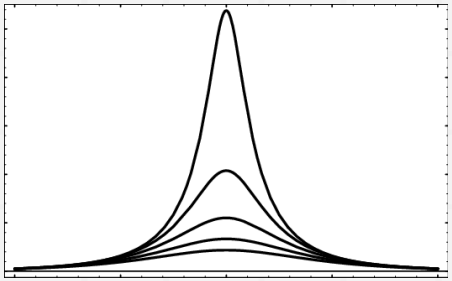
$\int_0^{} dy \int_0^{} f dx + \int_{1/\sqrt{2}}^{} dy \int_0^{}$

Misal, persamaan panas dengan sumber titik

$$u_{tt} = Du_{xx}$$
$$u(x,0) = M\delta(x)$$

Masalah ini dapat diselesaikan secara analitik, solusinya

$$u(x,t) = \frac{M}{\sqrt{4\pi Dt}} e^{-\frac{x^2}{4Dt}}$$



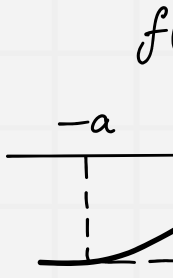
$\int_0^{} dy \int_0^{} f dx + \int_{1/\sqrt{2}}^{} dy \int_0^{}$

Namun, kalau masalah ini dimodifikasi sedikit saja

$$u_{tt} = Du_{xx} + uu_x$$
$$u(x,0) = M\delta(x)$$

Maka, belum tentu solusi analitiknya dapat dihitung

$2\sqrt{y^2-x^3}$



Tidak semua model matematika dapat diselesaikan

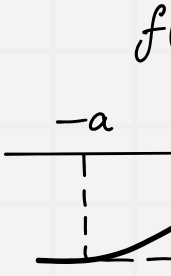
Beberapa model terlalu rumit untuk dihitung secara langsung (analitik)

$+3y)\,dy =$

$$\iiint x^2\,dx\,dy\,dz =$$

$2\sqrt{y^2-x^3}$

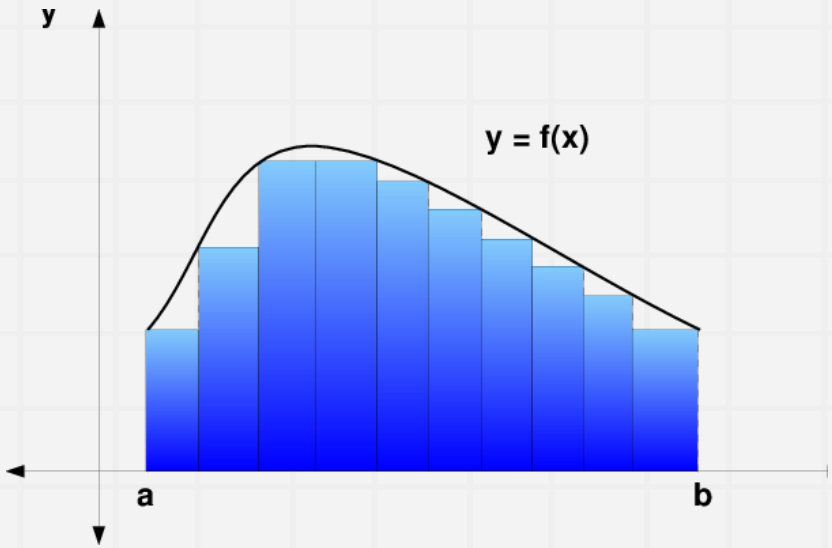
- Solusi matematis
  - Eksak (analitik)
  - Aproksimasi (pendekatan)
    - Asimtotik
    - Numerik



Model matematika dapat disederhanakan lagi untuk mendapatkan solusi yang mendekati (aproksimasi).

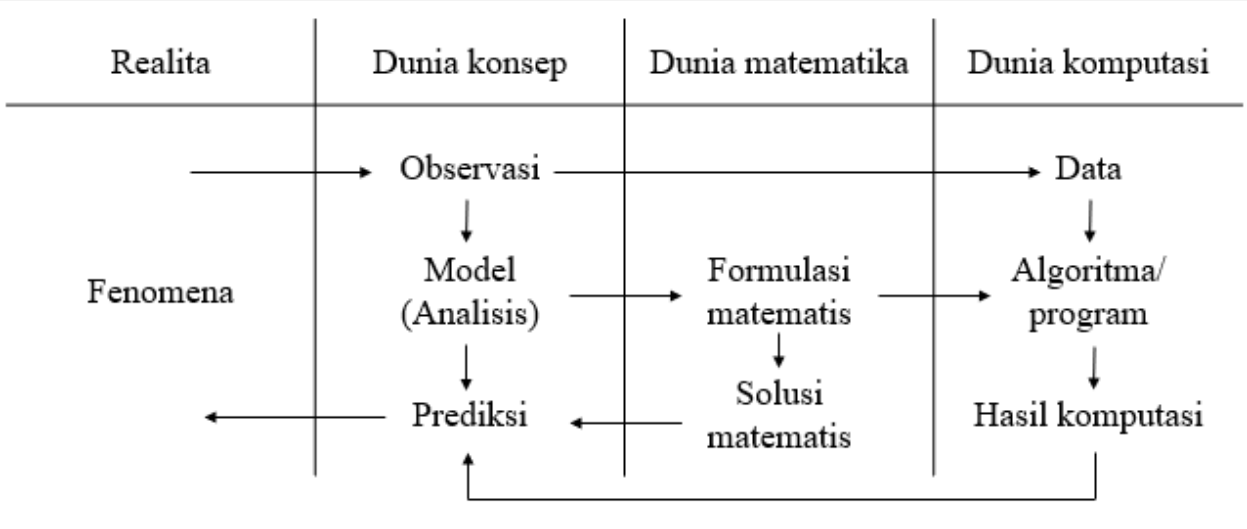
$+3y)\,dy =$

$\iiint x^2\,dx\,dy\,dz =$

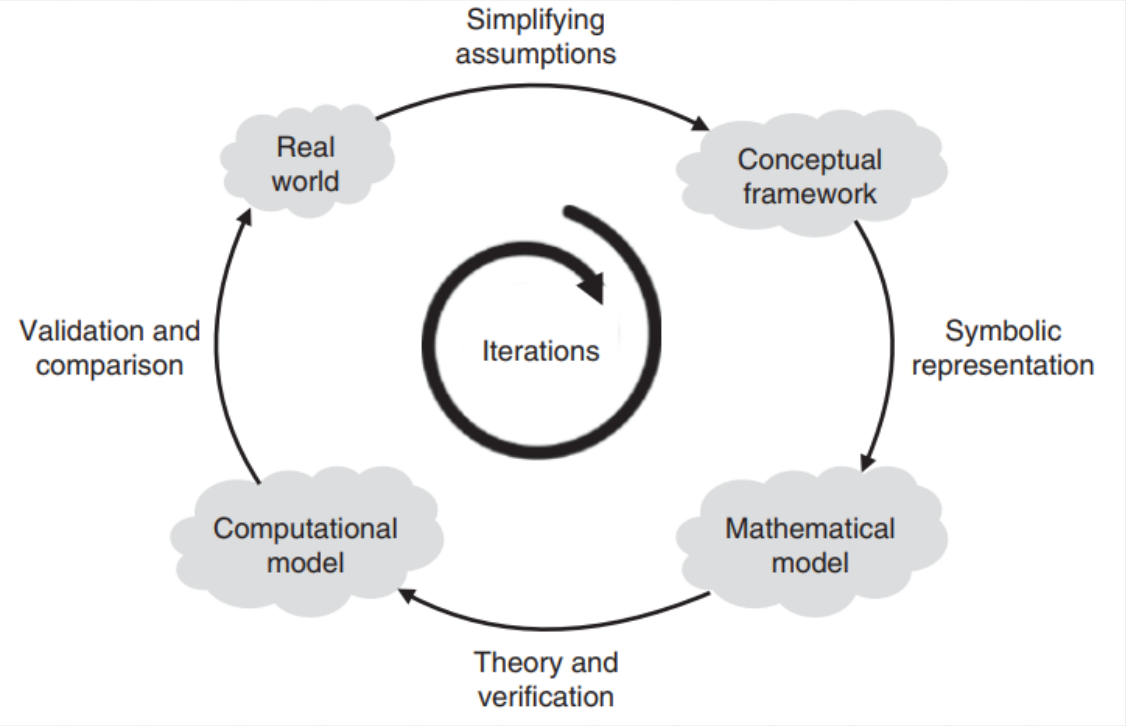


Beberapa aproksimasi dapat dihitung secara langsung. Namun sebagian melibatkan banyak **iterasi** dan **diskritisasi**

Dalam jumlah besar, perhitungan bisa sangat tidak efektif, sehingga diperlukan bantuan komputer



Model matematika terkadang perlu diubah menjadi sebuah program untuk menefektifkan perhitungan



Secara umum, peran 4 dunia itu dapat digambarkan sebagai proses siklik

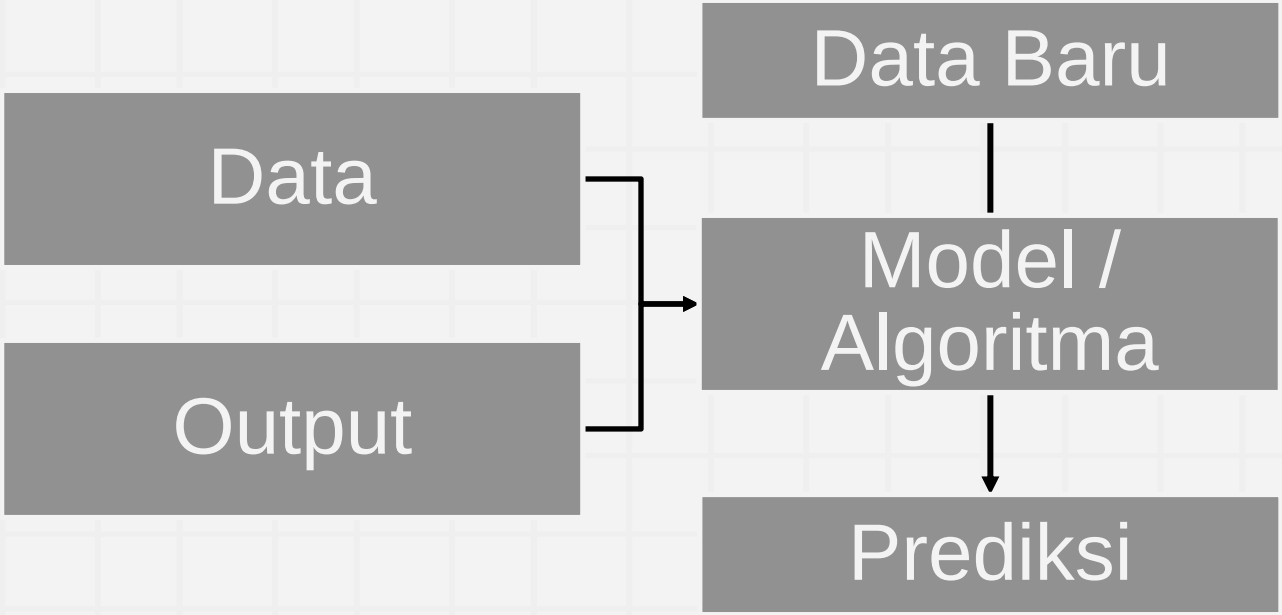
Ingat lagi dalam model komputasi

$2\sqrt{y^2-x^3}$

Tapi, tidak semua sistem diketahui algoritmanya

$10(x+3y)$
$\int x^2 dz =$

Bagaimana kalau dibalik?

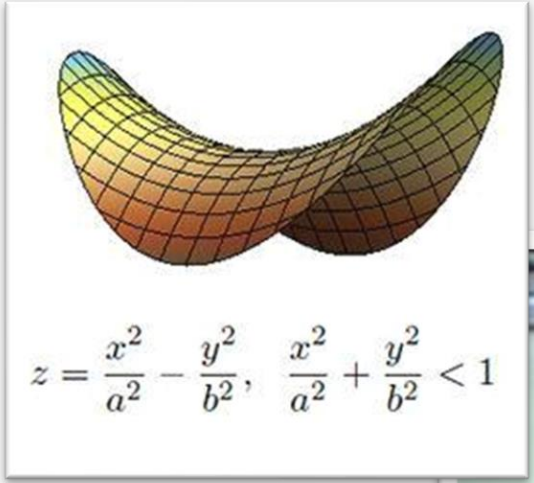


SEPERTI APA TOPIK-TOPIKNYA?

Model matematika dibangun dari gabungan topik-topik matematika murni

1

GEOMETRI + KALKULUS = GEOMETRI DIFERENSIAL

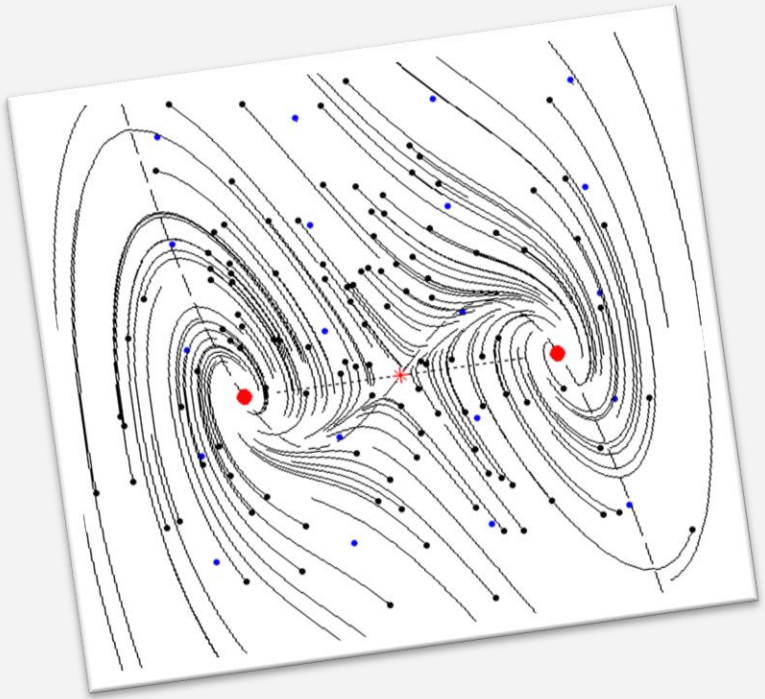


$$z = \frac{x^2}{a^2} - \frac{y^2}{b^2}, \quad \frac{x^2}{a^2} + \frac{y^2}{b^2} < 1$$

Contoh: Desain kurvatur, fisika relativitas, pemodelan membranae, analisis permukaan (computer vision)

2

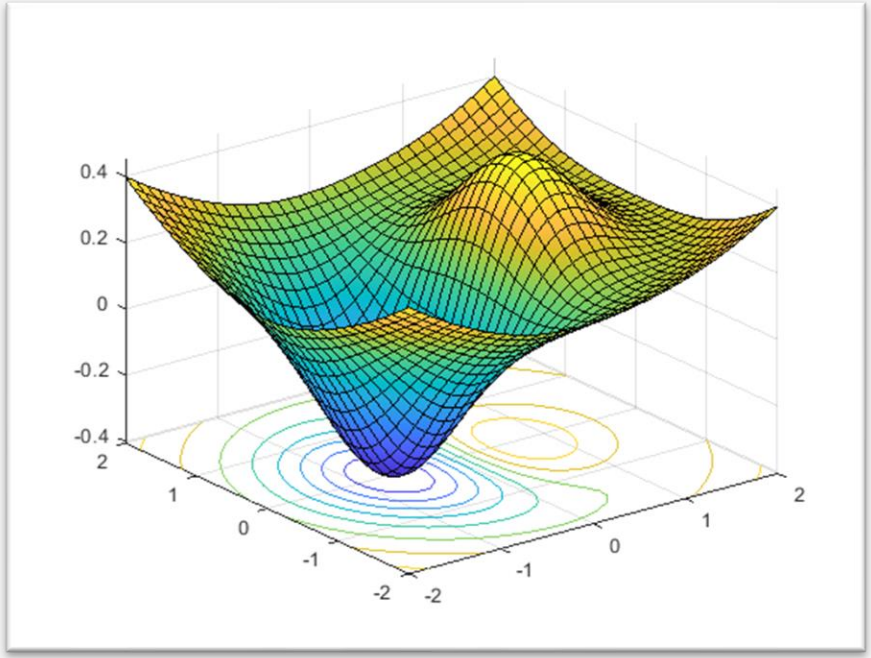
KALKULUS + ALJABAR LINEAR = SISTEM DINAMIK



Contoh: Analisis perubahan system, dinamika populasi, biomatematika, epidemologi, mekanika

3

KALKULUS + ALJABAR LINEAR = OPTIMISASI



Contoh: Penjadwalan, rekayasa kontrol, decision-making, machine learning, analisis efisisensi

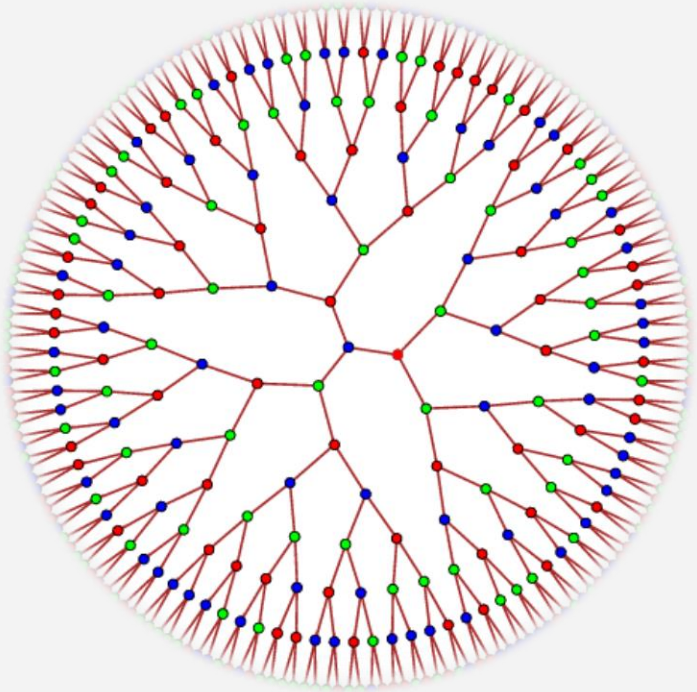
4

TEORI BILANGAN + STRUKTUR ALJABAR = KRIPTOGRAFI

Contoh: Teori Koding, Blockchain, Teori Informasi, Cybersecurity

5

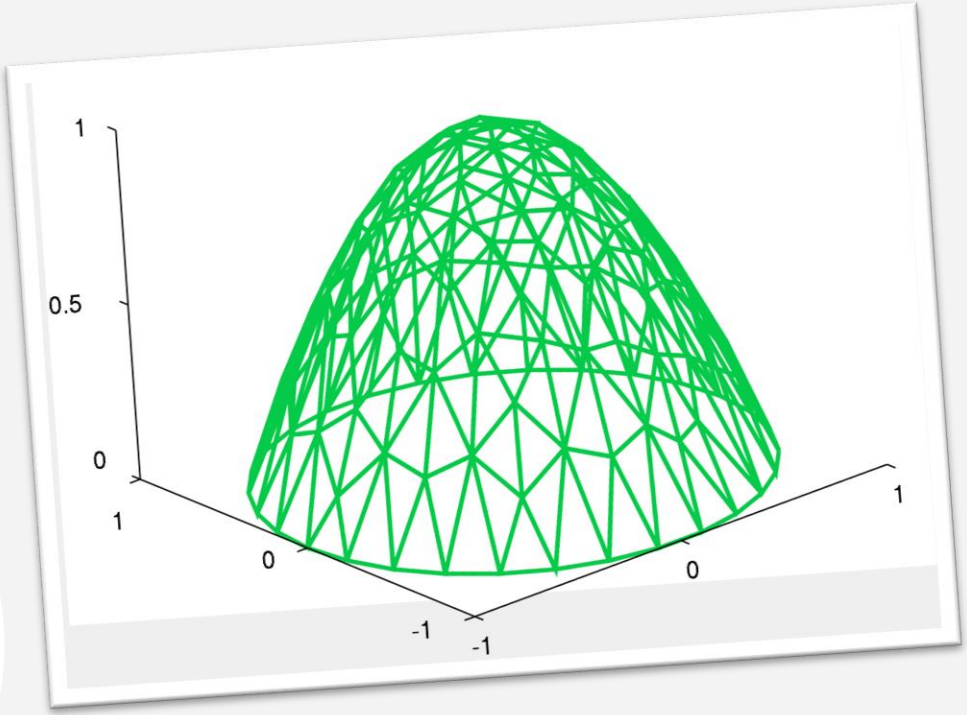
STATISTIKA + ALJABAR LINIER = PROSES STOKASTIK



Contoh: Teori Resiko, aktuaria, teori antrian, gerak acak, reinforcement learning

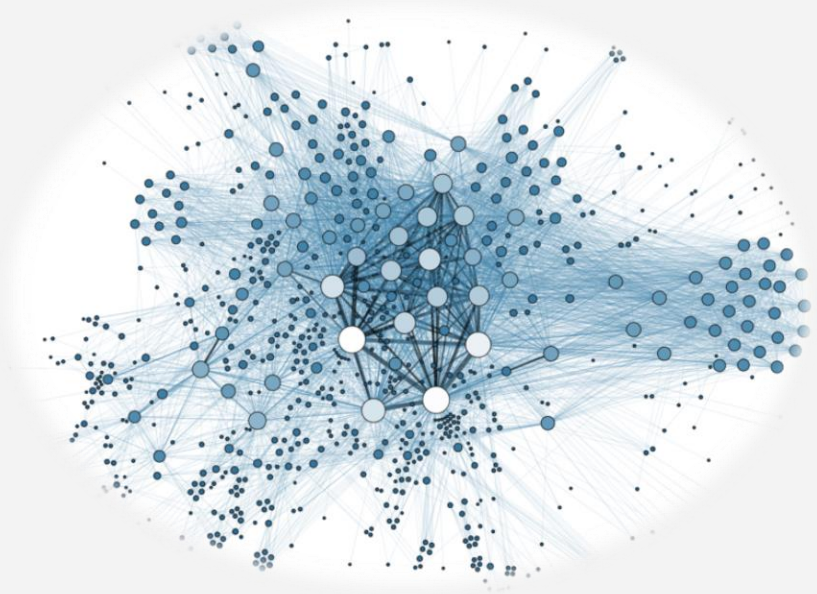
6

STATISTIKA + KALKULUS + MATDISKRIT = ANALISIS NUMERIK



Contoh: Regresi, Interpolasi, Persamaan Beda, Integrasi numerik

7

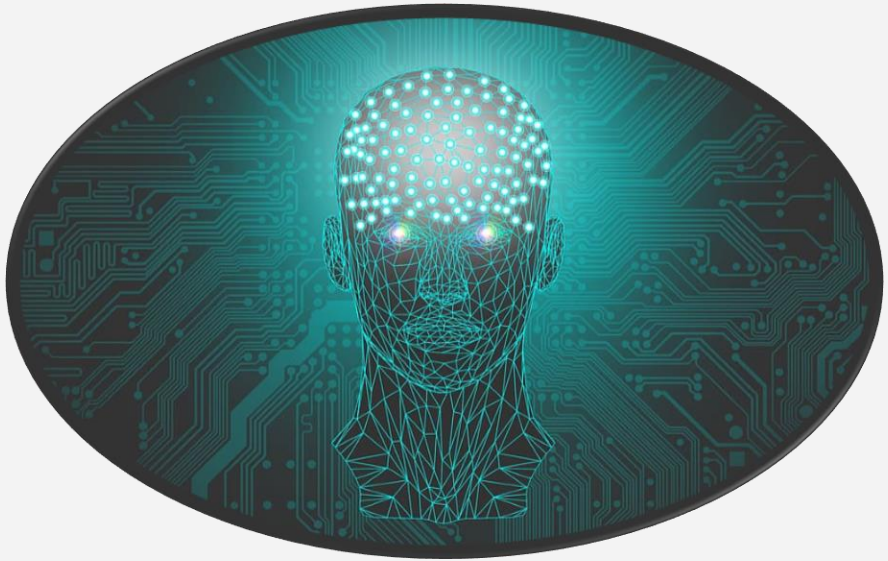


GRAF +
TOPOLOGI +
STATISTIK =
TEORI JARINGAN

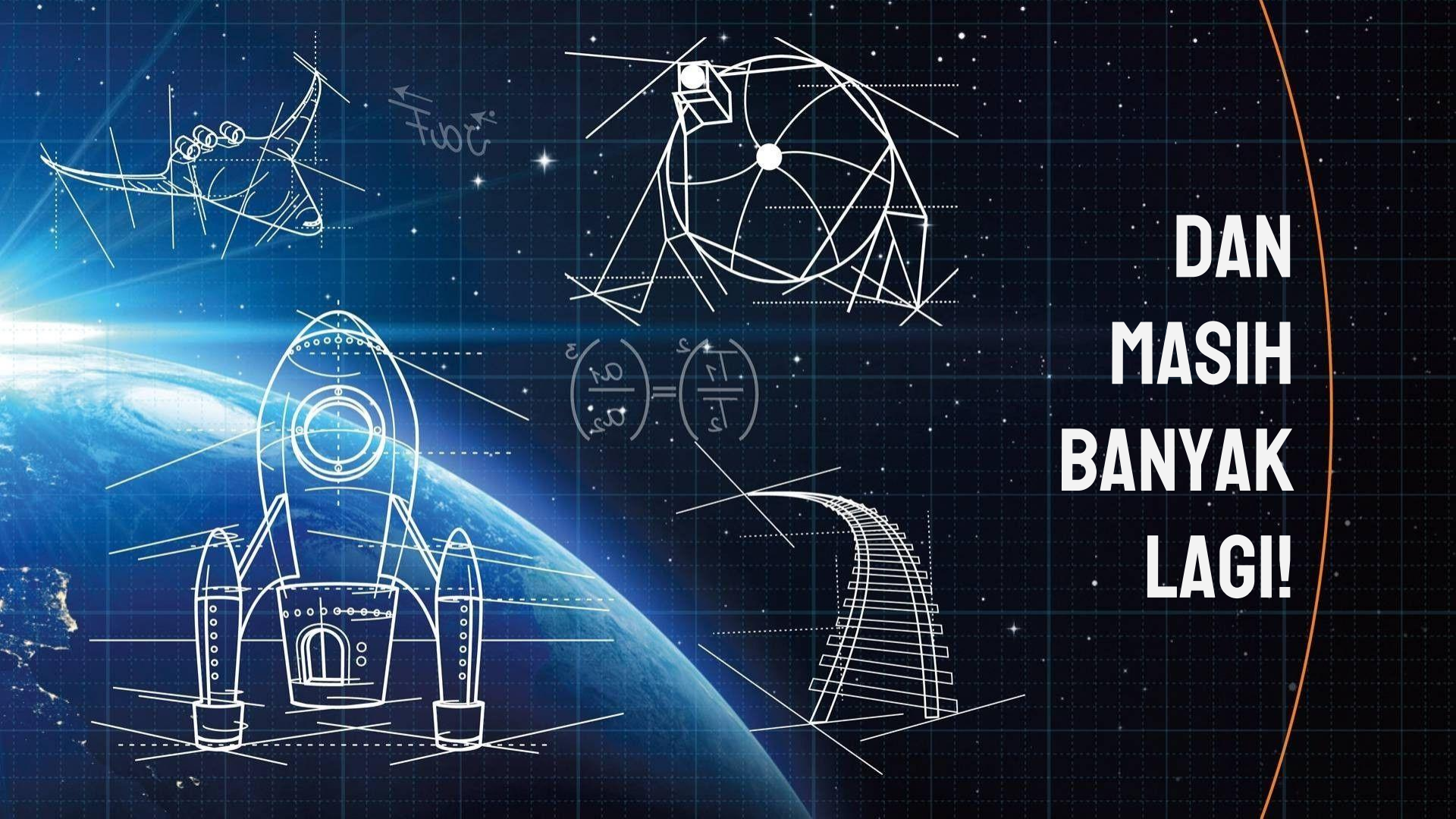
Contoh: Social Network Analysis, Computer Network

8

ALJABAR LINIER + KALKULUS + STATISTIK = MACHINE LEARNING

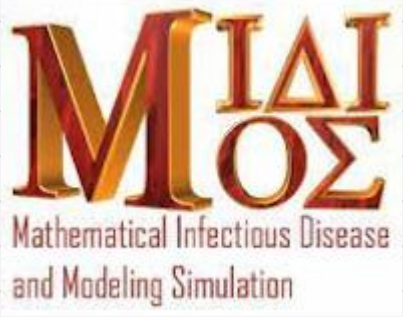


Contoh: Neural network, recommender system, sentiment analysis


DAN
MASIH
BANYAK
LAGI!

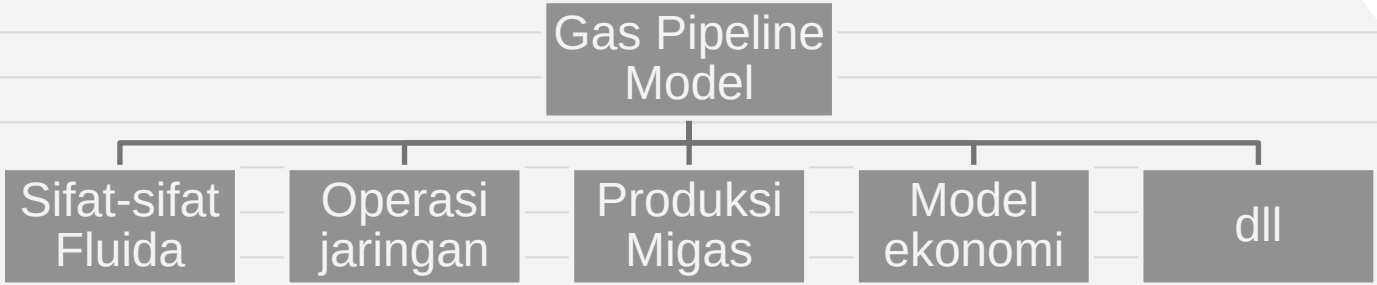
KASUS REALNYA?

Pusat Pemodelan Matematika dan Simulasi (PPMS) ITB



RC-OPPINET

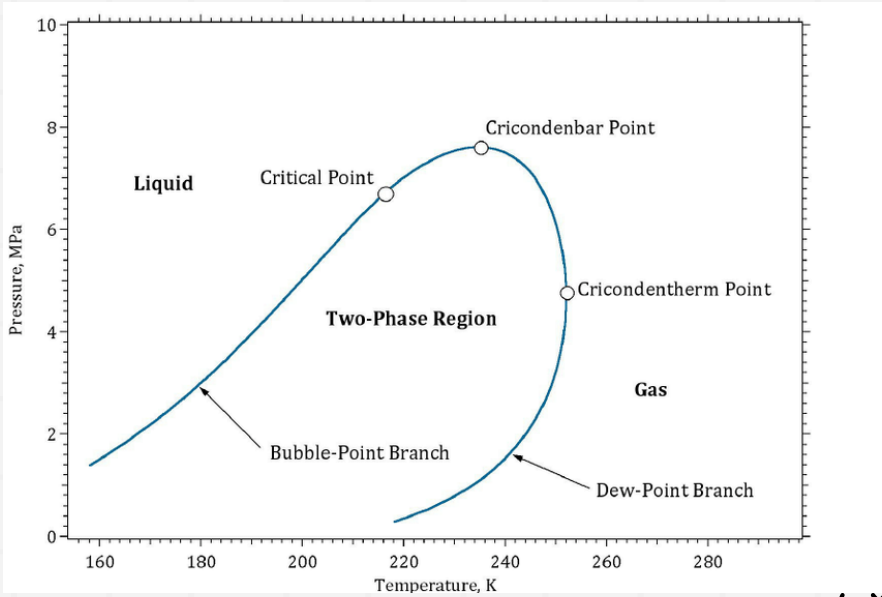
Optimization of Pipeline Network



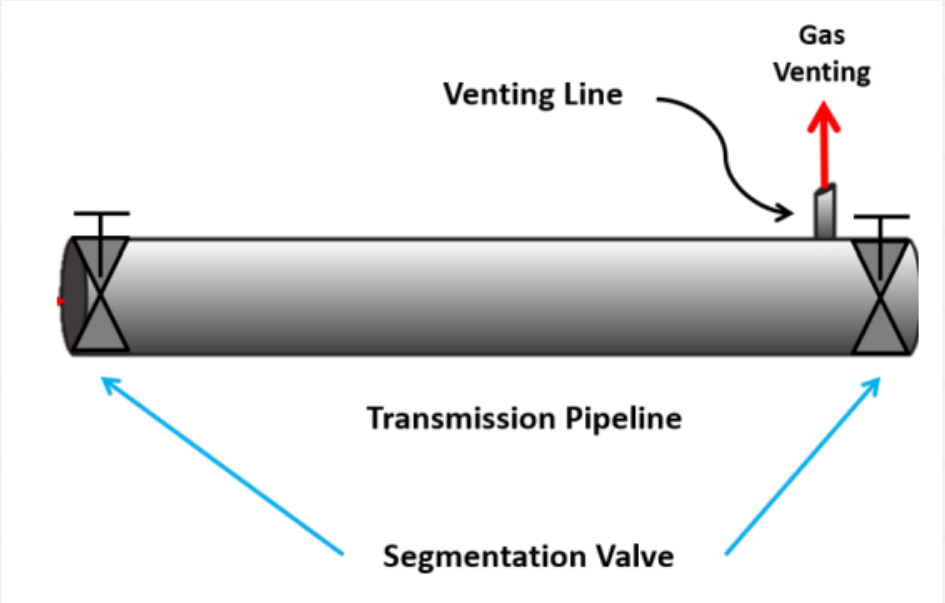
Fluid properties

$$f(n_v) = \sum_i \frac{z_i(K_i - 1)}{n_v(K_i - 1) + 1} = 0$$

$$n_l + n_v = 1$$

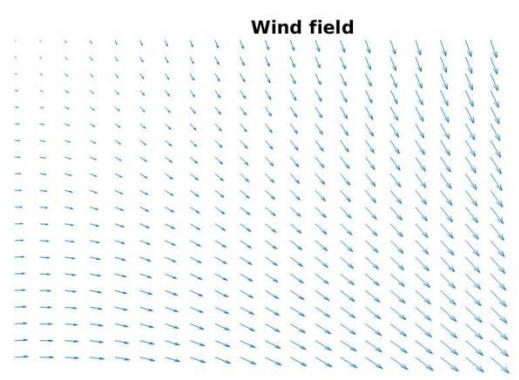


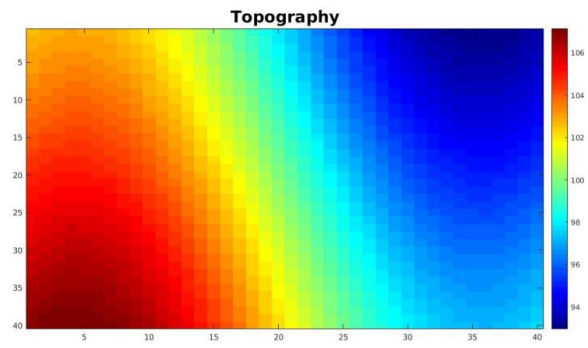
GAS VENTING

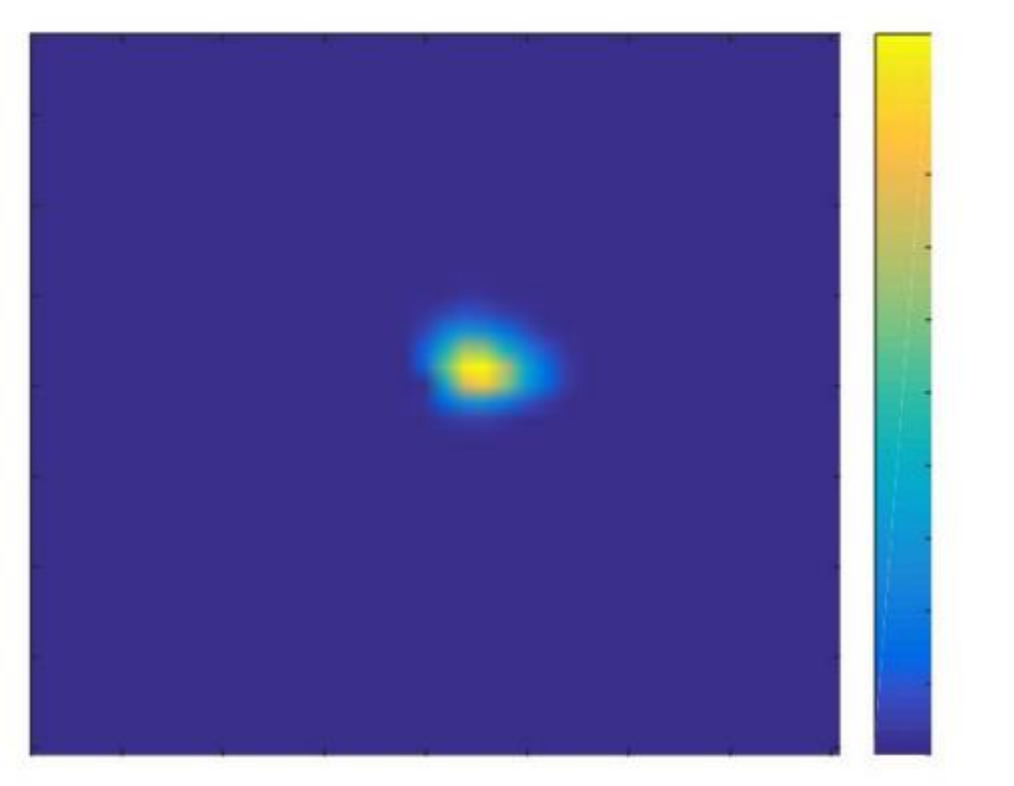


$$\frac{\partial T}{\partial t} = D\frac{\partial^2 T}{\partial x^2} - c(T - T_b) + \frac{\partial \rho}{\partial t}\alpha(T - T_s)\left[H(x-l) - H(x-l-d_V)\right] + \mu_{JT}\frac{\partial P}{\partial t} + \mathrm{sgn}(l-x)Q\frac{\partial T}{\partial x}.$$

Gas dispersion





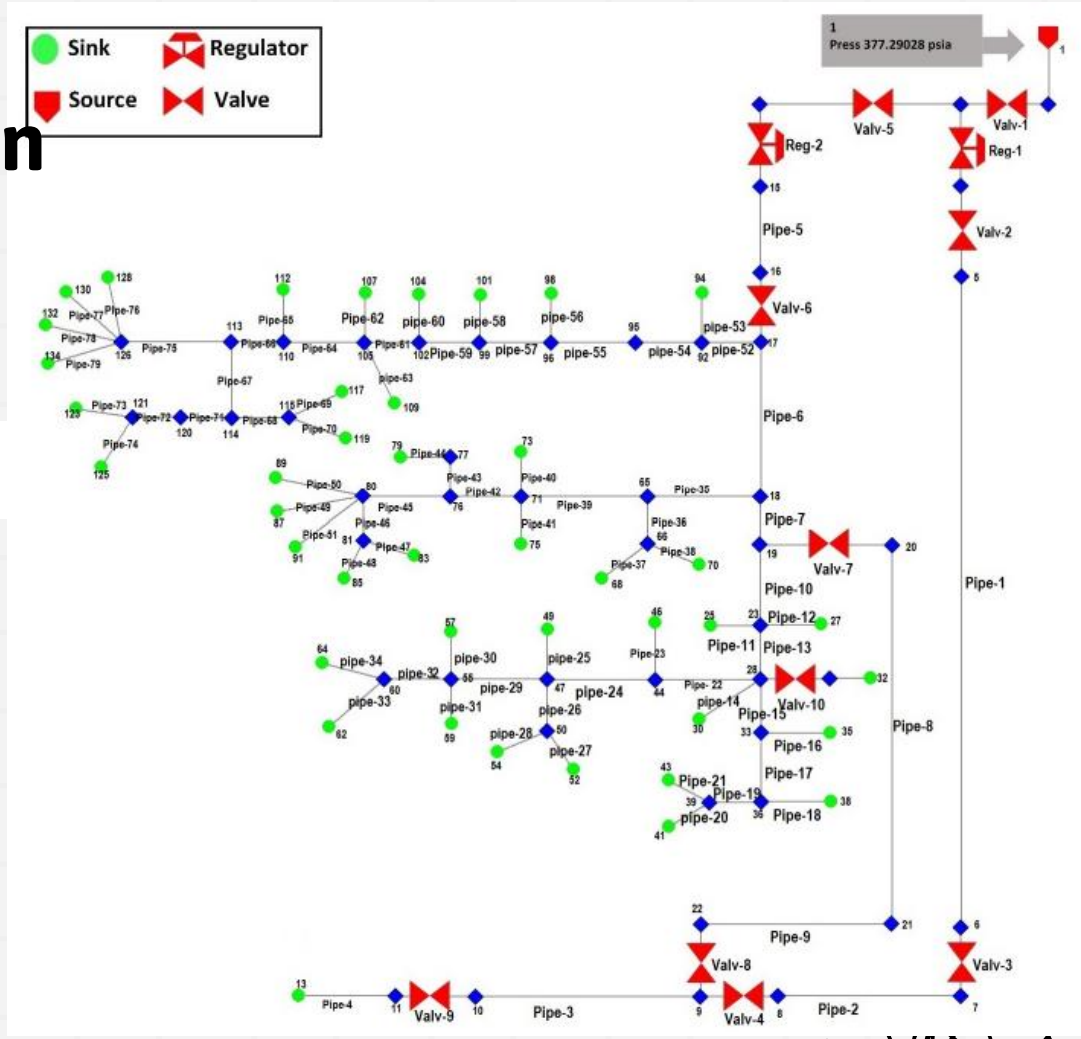


$$Dd(A_{ij}) = w_e(A_{ij+1} - A_{ij}) + w_w(A_{ij-1} - A_{ij}) + w_n(A_{i+1j} - A_{ij}) + w_s(A_{i-1j} - A_{ij})$$

Pressure distribution

$$f_m = Q_{jm} + Q_{mk} + QN_m = 0$$

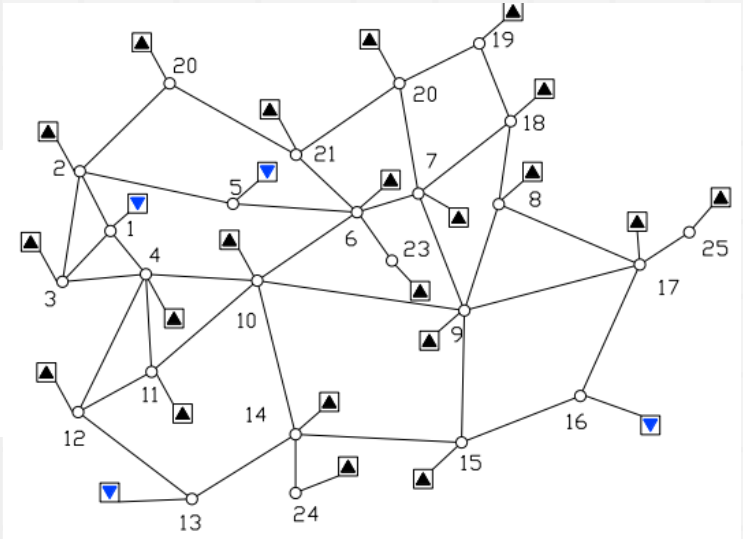
$$Q = a_1 \times E \left(\frac{T_b}{P_b}\right)^{a_2} \left(\frac{(|P_i^2 - P_j^2|)}{T_{avg} Z L_{ij}}\right)^{a_3} \left(\frac{1}{G}\right)^{a_4} ID_{ij}^{a_5}$$



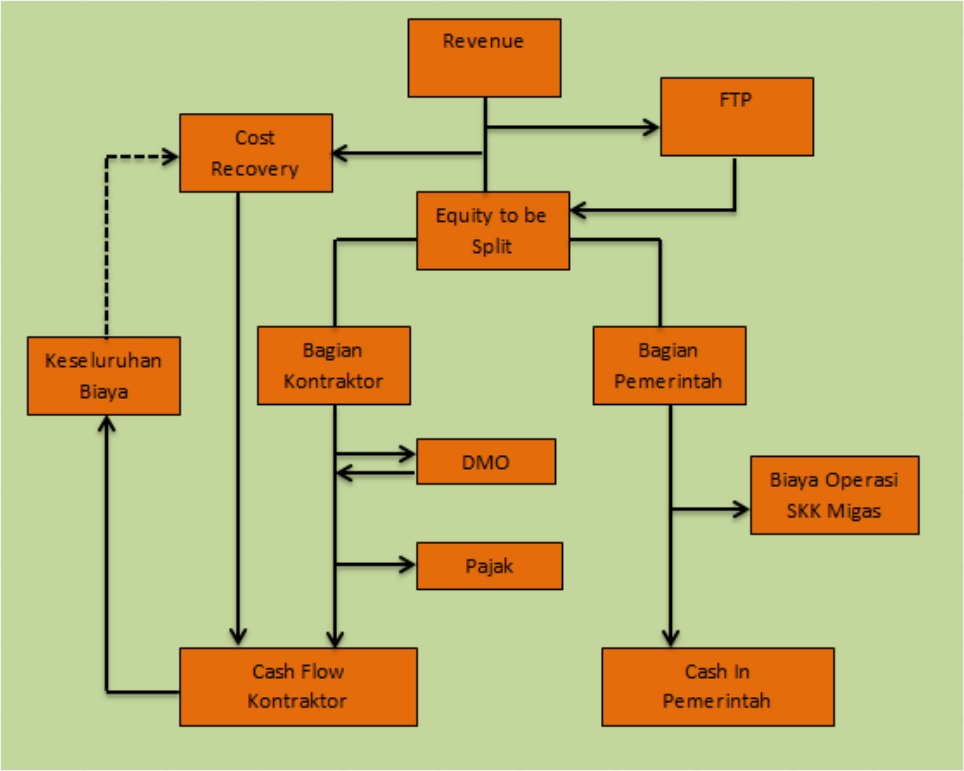
Model transient

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho w)}{\partial x} = 0$$

$$\frac{\partial (\rho w)}{\partial t} + \frac{\partial (\rho w w)}{\partial x} + \frac{\partial p}{\partial x} = -\frac{\lambda}{2}\frac{\rho w |w|}{d} - \rho g \sin\theta$$



Economical model

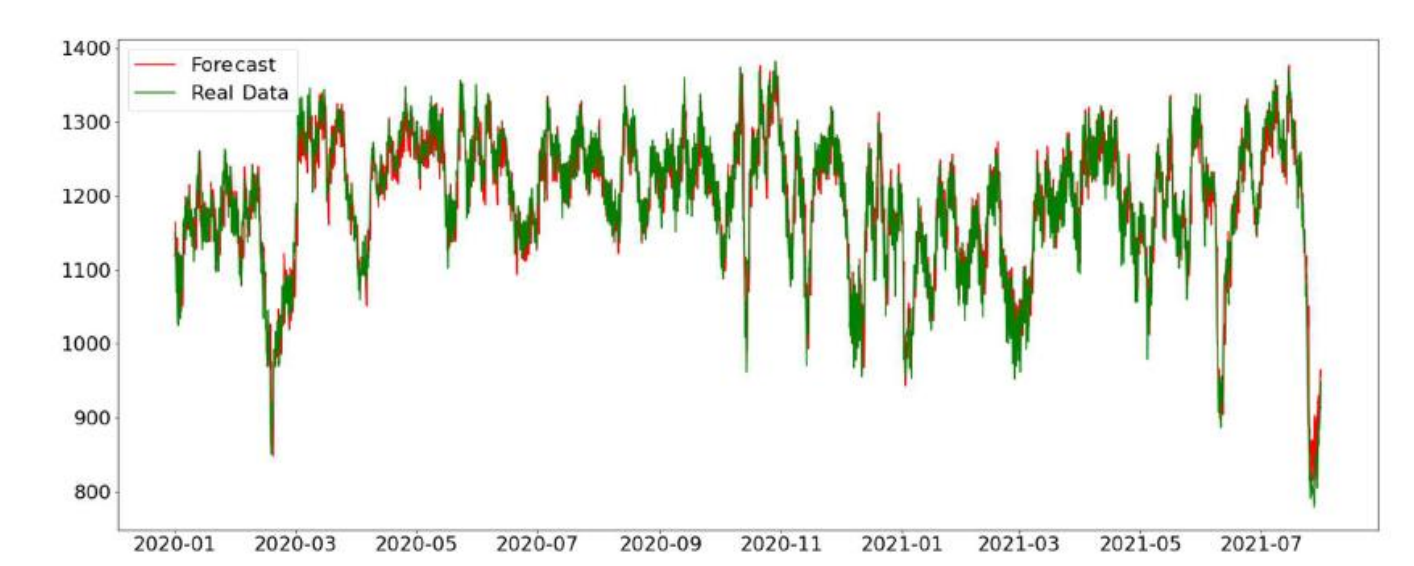


DENGAN BANTUAN DATA, LEBIH LUAS LAGI

Data Forecasting

Data deret waktu ada di banyak lini, siap untuk diramal.

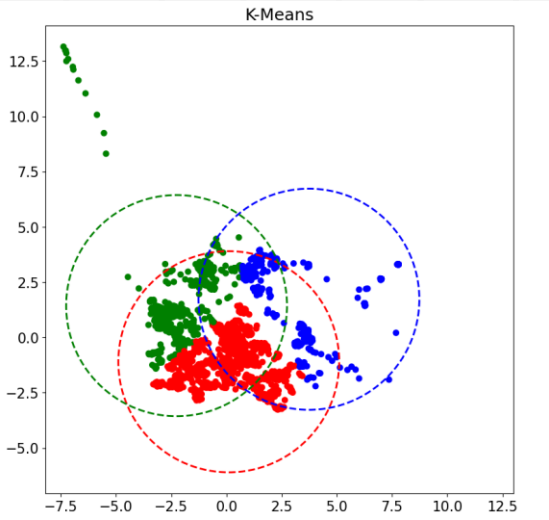
Teknik tradisional (ARIMA dan turunannya) sampai yang modern (Recurrent Neural Network dan turunannya) dapat diterapkan

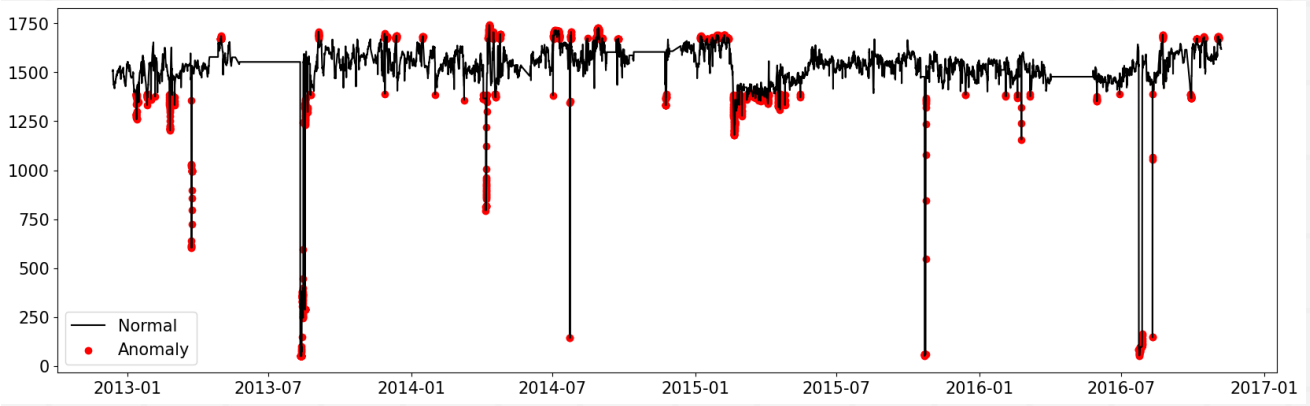


Anomaly Detection

Beberapa data perlu dideteksi anomalinya, kebutuhan untuk monitoring dan pencegahan risk.

Deteksi anomali dapat dilakukan dengan 2 cara, **supervised** dan **unsupervised**

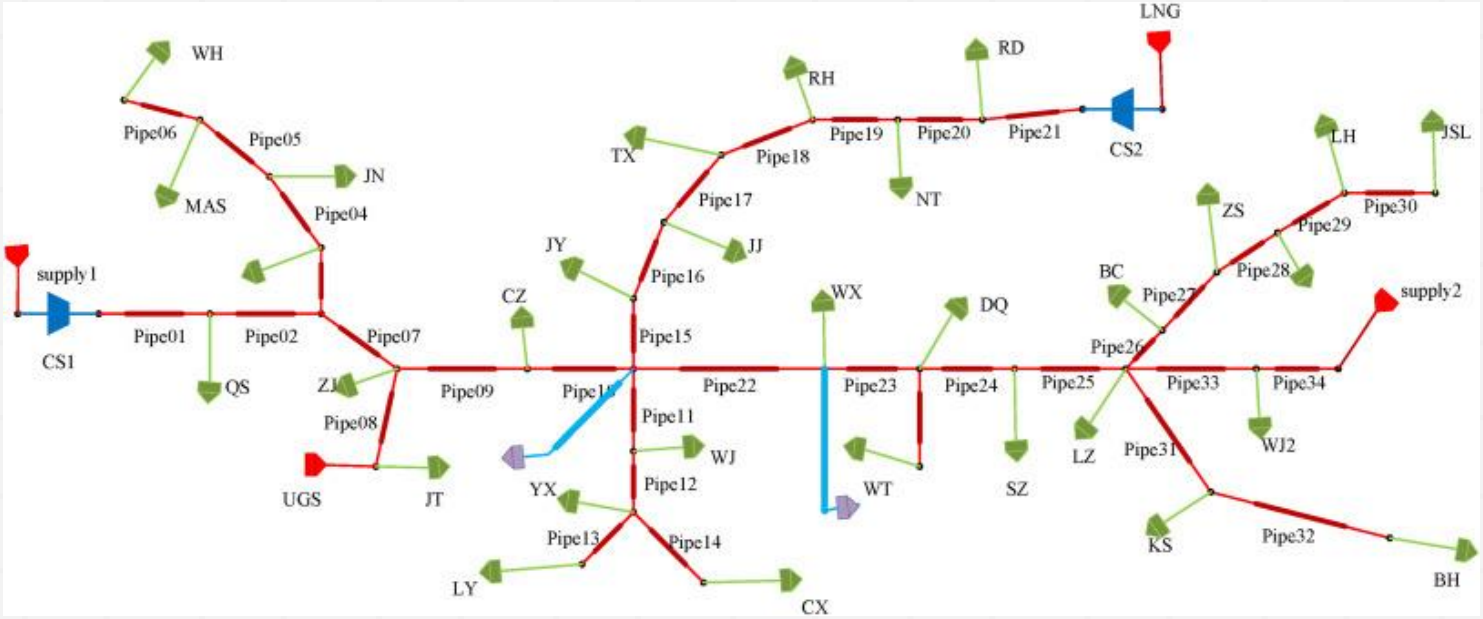




Graph Neural Network

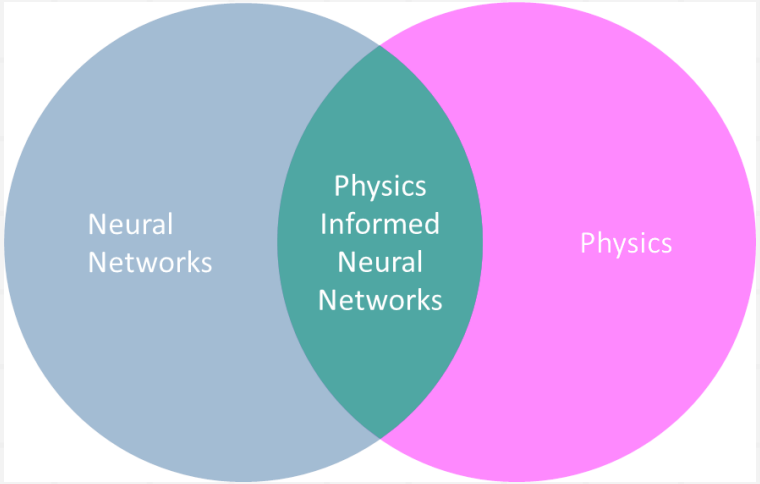
Jaringan pipa migas merupakan sistem yang kompleks sebuah graf.

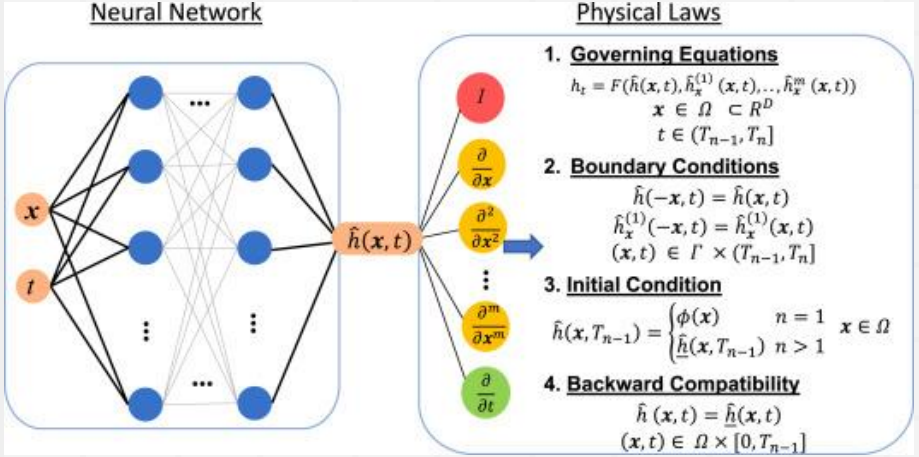
Dalam metode modern



Physics-Informed Neural Network

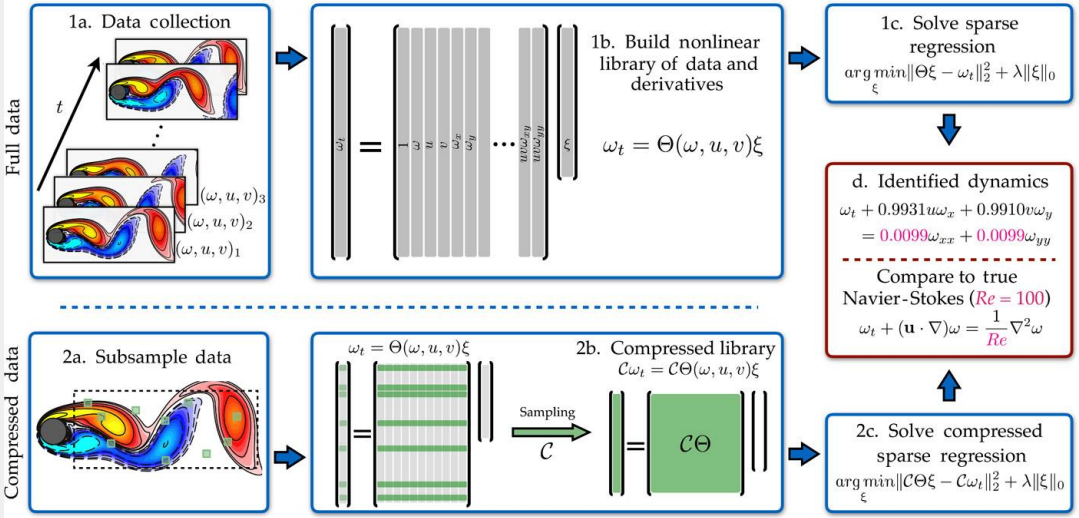
Kita juga bisa melakukan simulasi data dengan memanfaatkan informasi persamaan fisisnya



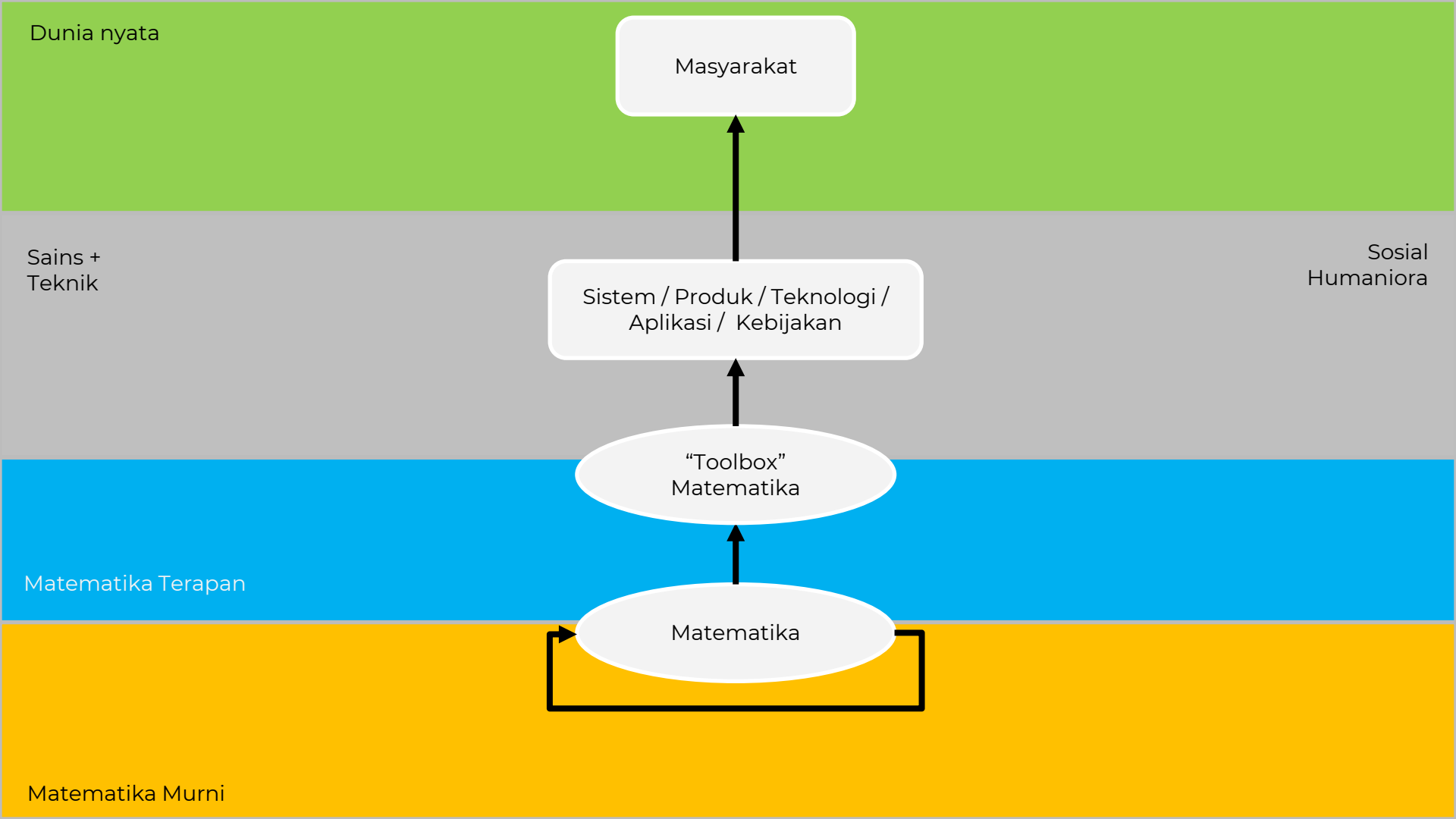


Sparse Identification of Nonlinear Dynamics (SINDy)

Sebaliknya, kita bisa memprediksi persamaan fisis dari data yang ada



BAGAIMANA CARANYA?


Dunia nyata
Masyarakat
Sains +
Teknik
Sosial
Humaniora
Sistem / Produk / Teknologi /
Aplikasi / Kebijakan
“Toolbox”
Matematika
Matematika Terapan
Matematika
Matematika Murni

Pemodelan merupakan titik perbatasan matematika dengan ilmu lain

Orang yang berada di perbatasan harus bisa komunikasi ke luar

01

Dalami dasar matematika dengan baik

02

Banyak mencoba masalah2 sederhana matematika terapan

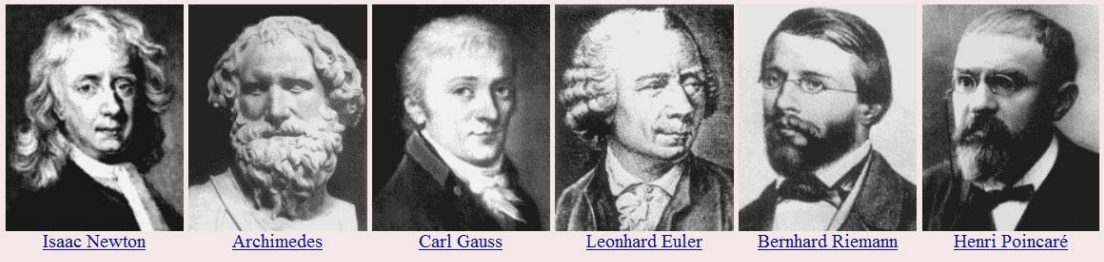
03

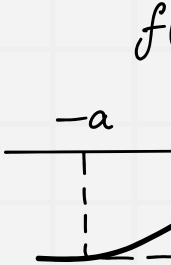
Banyak diskusi atau mencari tahu penggunaan matematika di bidang lain

04

Eksplorasi dan mulai projek-projek sederhana

$2\sqrt{y^2-x^3}$

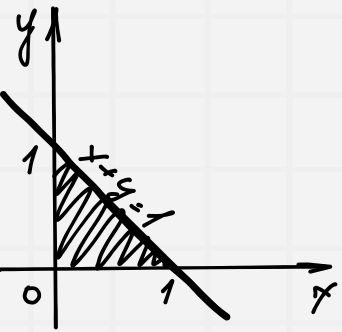


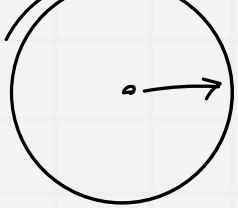


Banyak topik matematika berkembang dari interaksinya dengan ilmu lain

$+3y)\,dy =$

$\iiint x^2\,dx\,dy\,dz =$

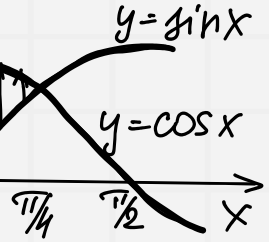


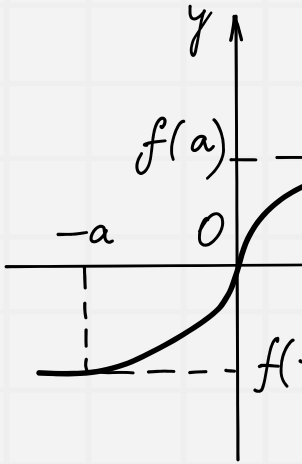


$S = 2\pi R$

Thanks!

Do you have any questions?





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$2\sqrt{y^2 - x^2}$