

principles

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maths prof in 1952 - 1970

... member of the US National Academy of Sciences, 1981

$f(x) \Rightarrow f: \mathbb{R} \rightarrow \mathbb{R}$

$f: \mathbb{R}^n \rightarrow \mathbb{R}$

integrals, numerical methods -
kings, king, king, king, king
king, king, king, king, king

integration: numerical integration -
numerical integration, numerical integration, numerical integration
(numerical integration, numerical integration, numerical integration)

الله يحيى

$$f: \mathbb{R} \rightarrow \mathbb{R}$$

23's place random - r/a/o $\mathbb{R}^* \subseteq \mathbb{R}$

$0 \in \mathbb{R}^*$, $x^* \in \mathbb{R}^*$ \mapsto $|x| - 15$ e, $x \in \mathbb{R}$

$$\therefore 0^\alpha = 0$$

$$\frac{|x - x^*|}{|x|}$$

$f(x)$ \approx $\frac{1}{2}x^2 + \frac{1}{3}x^3 + \frac{1}{4}x^4$

うれしいこと
× と どうして そこ が

? なぜかしらべる

$$f(x^*) = f(x'), \quad f(x), \quad x, x^*$$

$$\frac{|x' - x|}{|x'|} |x^* - x| \sim y,$$

$$\left| \frac{f(x^*) - f(x)}{f(x)} \right| = \left| \frac{f(x') - f(x)}{f(x)} \right| =$$

$$\left| \frac{(f(x') - f(x))(x^* - x)}{(x' - x) \cdot f(x)} \right| \leq \frac{|x^* - x|}{|x|}.$$

$$\left| \frac{(f(x') - f(x)) \cdot x}{(x' - x) \cdot f(x)} \right| \approx \left| \frac{x f'(x)}{f(x)} \right| \cdot \frac{|x^* - x|}{|x|}$$

$f \in$ 23rd condition interval

κ (condition number) $x \rightarrow$

$$\text{cond}(f)(x) = \left| \frac{x \cdot f'(x)}{f(x)} \right|$$

$(X, f(x) \neq 0 \text{ and } f'(x) \neq 0)$

$$, f(x) = ax + b \quad \text{for } \text{cond}(f)(x) = \left| \frac{x \cdot a}{ax + b} \right| = \left| 1 - \frac{b}{ax + b} \right|$$

" for 21st problem solution

$$I_n = \int_0^1 \frac{t^6}{t+5} dt \quad \text{from } u/v \text{ method}$$

$$I_0 = \int_0^1 \frac{dt}{t+5} = \left. \ln(t+5) \right|_0^1 = \ln\left(\frac{6}{5}\right)$$

$$I_{n+1} = \int_0^1 \frac{t^{n+1}}{t+s} dt = \int_0^1 t^n \cdot \frac{t+s-s}{t+s} dt =$$

$$-5 \int_0^1 \frac{t^n}{t+s} dt + \left. \frac{t^{n+1}}{n+1} \right|_0^1 = -5 I_n + \frac{1}{n+1}$$

$\sum_{n=0}^{\infty}$

$$I_n = f_n(I_0) \quad \underline{f_n(x) = (-5)^n x + b_n}$$

$b_n \in \mathbb{R}$ ($\rightarrow \mathbb{C}^1$, vgl.)

$$(\text{and } f_n)(I_0) = \left| \frac{\int_0^1 f_n(t) dt}{I_0} \right| =$$

$$s^n \cdot \left| \frac{I_0}{I_n} \right| \geq s^n$$

$$I_n = \underbrace{I_{n+1} - \frac{1}{n+1}}_{= 5}$$

$$k \gg n$$

$$I_n \approx g_n(I_k) \quad n-k < 0$$

$$g_n^{(k)} = (-5)^{\overbrace{k}^{n-k}} x + c_n$$

$$\text{cond}(g_n)(I_k) = \left| \frac{I_k \cdot (-5)^{n-k}}{\sum_n} \right| =$$

$$5^{n-k} \left(\frac{I_k}{\sum_n} \right) \leq 5^{n-k}$$

a_1

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$$(x_1^*, \dots, x_n^*) \hookrightarrow (x_1, \dots, x_n)$$

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\sim $\| \cdot \| : V \rightarrow \mathbb{R}_{\geq 0}$ $= \{ x \in \mathbb{R} / x \geq 0 \}$

$V = 0 \quad \|V\| = 0 \quad \|V\| = 0 \quad .1$
 $\|av\| = |a| \cdot \|v\| \quad \forall v \in V, a \in \mathbb{R} \quad .2$
 $\forall v \in V \quad .3$

$$\|u+v\| \leq \|u\| + \|v\|$$

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$\mathbb{R} \ni p \geq 1$, $V = \mathbb{R}^d$ if $p \geq 1$

$$\|\langle x_1, \dots, x_d \rangle\|_p = \sqrt[p]{\sum |x_i|^p}$$

/ euclidean norm)

$$\|\langle x_1, \dots, x_d \rangle\|_1 = \sum |x_i|$$

$$\|\langle x_1, \dots, x_d \rangle\|_2 = \sqrt{\sum x_i^2}$$

" $p = \infty$ "

$$\|\langle x_1, \dots, x_d \rangle\|_\infty = \sup \{|x_i|\}$$

, for $\|\cdot\| = \sqrt{\sum x_i^2}$ euclidean norm

$$d(u, v) = \|u - v\|$$

now (v_i) , $i \sim 30$ $v_i \in V$ is

$$\cdot \|v_i - v\| \rightarrow 0 \quad \forall \epsilon \quad \forall \delta$$

设 γ/Γ_β 为 γ 的 单位向量

$\|\cdot\|_2$, $\|\cdot\|_1$, $\|\cdot\|_\infty$ 为

该类型的 γ/Γ_β 的范数

$v \in V$ 时 (v_i) 为 Ω 中的 δ .

$\|v_i - v\|_2 \rightarrow 0$ 则 $\|v_i - v\|_1 \rightarrow 0$

由 $\exists C > 0$ 使得 $\|v\|_1 \leq C \|v\|_2$

$\frac{1}{C} \|v\|_1 \leq \|v\|_2 \leq C \|v\|_1$, $\forall v \in V$

\mathbb{R}^d 为 \mathbb{R}^d 上的 单位向量

\mathbb{R}^d 为 \mathbb{R}^d 上的 单位向量

$$\frac{\|x^* - x\|}{\|x\|}$$

רעיון $T: V \rightarrow V$ ו- x'

$$\| \cdot \|_V \text{ גודלה } \cup \text{ אוסף } \sim, \omega'$$

$$V \text{ סט } \| \cdot \|_V \text{ -י } V \text{ סט}$$

השאלה היא אם $\|x^*\|_V \leq \|x\|_V$

: רעיון גודלה T כפונקציית

$$\frac{\|Tx^* - Tx\|_V}{\|Tx\|_V} = \frac{\|T(x^* - x)\|_V}{\|T(x)\|_V} =$$

$$\frac{\|T(x^* - x)\|_V}{\|T(x)\|_V} \cdot \frac{\|x^* - x\|_V}{\|x\|_V} \leq \frac{\|T\| \cdot \|x\|_V}{\|T(x)\|_V} \cdot \frac{\|x^* - x\|_V}{\|x\|_V}$$

Recursive algorithm $T: U \rightarrow V$

רְבָבָה, וְנֵנוּן 'מִקְרָב' כְּבָבָה)בָּבָבָה(

$$\|T\| = \sup_{x \neq 0} \frac{\|T(x)\|_v}{\|x\|_v} = \sup_{\{x | \|x\|_v = 1\}} \|T(x)\|_v$$

N'is Sg Nprg * Hom (U,V)

$\gamma \circ \gamma^{-1}(\tau) \mapsto ||\tau||$. $\gamma \circ \gamma^{-1}(\tau)$

גָּדוֹלָה מְאֻמָּרָה

ת ס 23 נג רוגר ירל

لـ (نـ) X الـ (جـ)

$$\text{cond}(\tau)(x) = \frac{\|\tau\| \cdot \|x\|}{\|\tau(x)\|}$$

$x = T^{-1}(y)$ เมื่อ y เป็นค่าของ T และ

$\text{cond}(\tau) :=$

$$\sup_x \text{cond}(\tau)(x) = \|\tau\| \cdot \|\tau^{-1}\| \quad \text{sic!}$$

zu $\|\tau\|$ kann man nur $\|\tau x\|$

und $\|\tau^{-1}x\|$ für $\tau x = b$

b ist die ursprüngliche Vektoren

? b^* ?

: $(\tau \circ \delta, \tau \circ \gamma)$

$$\tau_n = \begin{pmatrix} 1 & \frac{1}{2} & \dots & \frac{1}{n} \\ 0 & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & 0 \end{pmatrix}$$

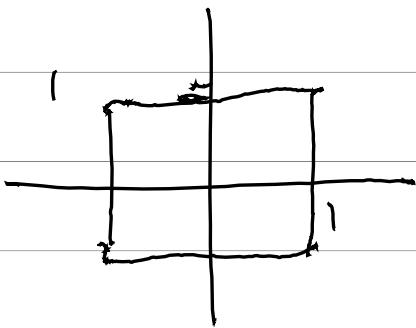
$$\text{Cond}_2 \tau_n = \frac{(V_2 + 1)^{n+4}}{\sum_{k=1}^{n+4} k \cdot \sqrt{\tau_n}}$$

Linear transformation $T: U \rightarrow V$

$$U = \mathbb{R}^n, \quad V = \mathbb{R}^m \quad \| \cdot \| = \| \cdot \|_\infty$$

'?' for and \mathbb{R}^n to \mathbb{R}^m

$$\begin{matrix} (a_{ij})_{1 \leq i \leq n} \\ 1 \leq j \leq m \end{matrix} \Rightarrow \text{3 rows}$$



$$\| T \| = \max_j \sum_{i=1}^n |a_{ij}|$$



$$X = 17$$

$$f: \mathbb{R} \rightarrow \mathbb{R}$$

$$\text{cond}(f)(x) = \frac{|x| / |f'(x)|}{|f(x)|}$$

$$y = -17 + 8$$

$$2 \cdot 17 = 34$$

$$T: U \rightarrow V \quad . \quad V, W, V$$

$$\|T\| = \sup_{\|u\|=1} \|Tu\|$$

$$\text{cond}(T)(u) = \frac{\|u\| \cdot \|T\|}{\|Tu\|} \leq \|T^{-1}\| \cdot \|T\|$$

$\text{cond}(T)$

$$[1 \cdot 1]$$

$$f: \mathbb{R}^2 \rightarrow \mathbb{R}$$

Übung 3

$$f(x, y) = x + y$$

$$\text{cond}(f)(x, y) = \frac{\|\langle x, y \rangle\| \cdot \|f\|}{|x+y|} = \frac{\max(|x|, |y|) \cdot 2}{|x+y|} \quad \|f\| = \|f\|_\infty$$

$$f: \mathbb{R}^n \rightarrow \mathbb{R}^m . 2$$

$$x^* \in \mathbb{R}^{n^*}, x \in \mathbb{R}^n$$

$$\frac{\|f(x^*) - f(x)\|}{\|f(x)\|} =$$

$$\frac{\|f(x^*) - f(x)\| \cdot \|x\| \cdot \|x^* - x\|}{\|f(x)\| \cdot \|x\| \|x^* - x\|} \approx \varepsilon$$

$$\frac{\|\underline{df(x)}(x^* - x)\| \cdot \|x\| \cdot \varepsilon}{\|f(x)\| \cdot \|x^* - x\|} \leq \frac{\|\underline{df(x)}\| \cdot \|x\| \cdot \varepsilon}{\|f(x)\|}$$

$$\text{cond}(f)(x) = \frac{\|\underline{df(x)}\| \cdot \|x\|}{\|f(x)\|}$$

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$f: \mathbb{R}^n \rightarrow \mathbb{R}^m$ \hookrightarrow $\mathbb{R}^n \times \mathbb{R}^m$

$f_i: \mathbb{R}^n \rightarrow \mathbb{R}$ \hookrightarrow \mathbb{R}^m

For $x \in \mathbb{R}^n$ $\exists i \in \{1, \dots, m\}$ such that

$x_j \neq 0$ for $j \neq i$ $\Rightarrow f_i(x) \neq 0$

$(\text{cond}_{x_j}(f_i))_{j \in \mathbb{N}}$

$f: \mathbb{R}^2 \rightarrow \mathbb{R}^2$ Ex 3

$$f(x, y) = \left(\underbrace{\frac{1}{x} + \frac{1}{y}}, \underbrace{\frac{1}{x} - \frac{1}{y}} \right)$$

$$df = \begin{pmatrix} -\frac{1}{x^2} & -\frac{1}{y^2} \\ -\frac{1}{x^2} & \frac{1}{y^2} \end{pmatrix}$$

$$\text{cond}(f)(x, y) = \max(|x|, |y|) \cdot \max\left(\frac{1}{x^2}, \frac{1}{y^2}\right)$$

$\max\left(\left|\frac{1}{x} + \frac{1}{y}\right|, \left|\frac{1}{x} - \frac{1}{y}\right|\right)$

$$f_1(x, y) = \frac{1}{x} + \frac{1}{y} \quad f_2(x, y) = \frac{1}{x} - \frac{1}{y}$$

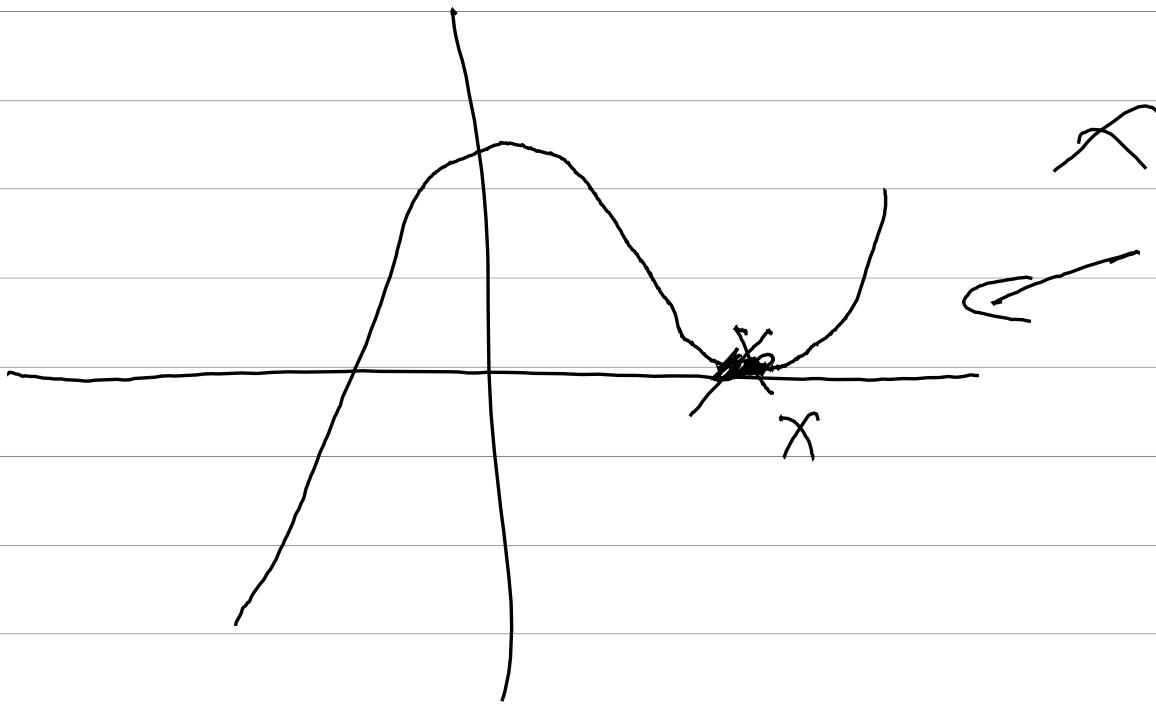
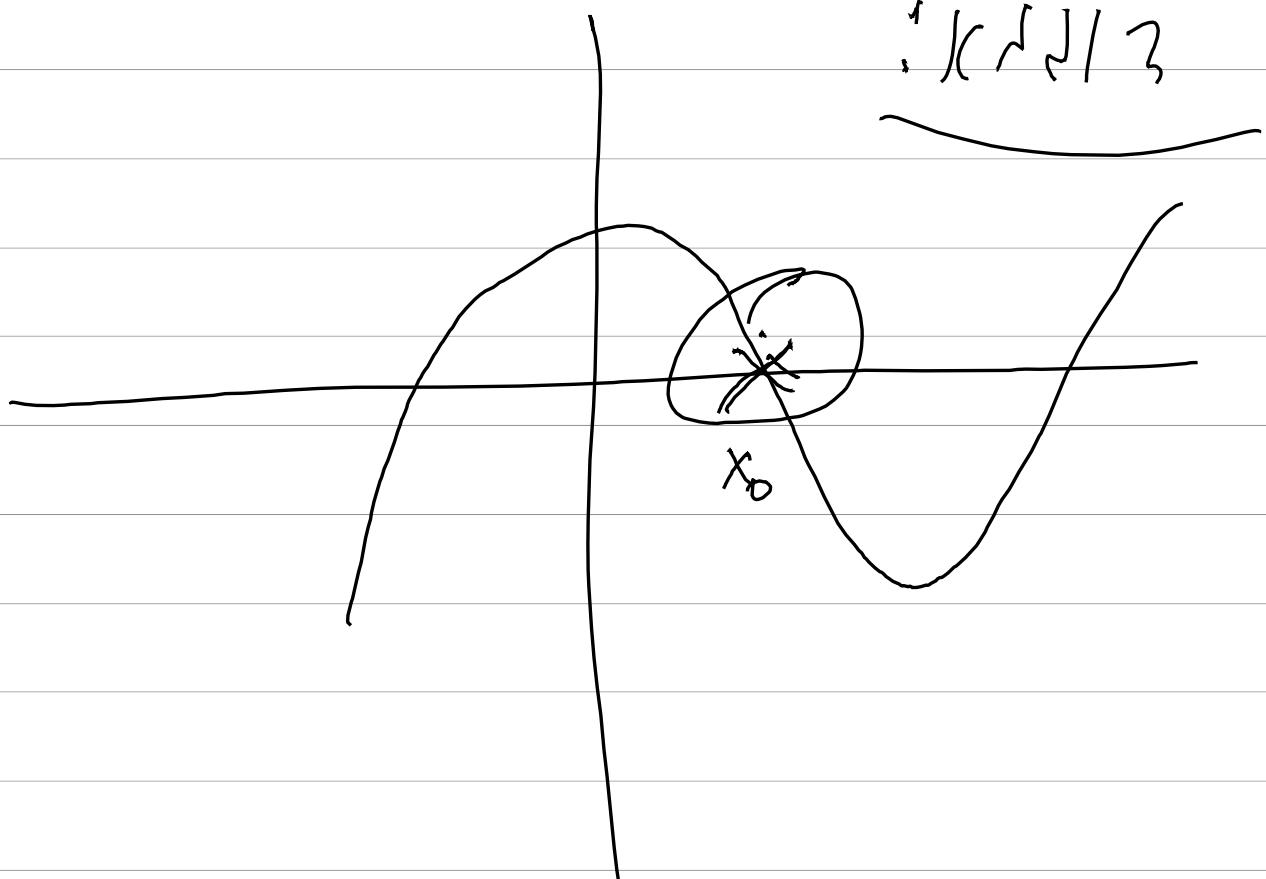
$$\text{cond}_x(f) = \frac{|x| \cdot \frac{1}{x^2}}{\left|\frac{1}{x} + \frac{1}{y}\right|} \quad \frac{|y| \cdot \frac{1}{y^2}}{\left|\frac{1}{x} + \frac{1}{y}\right|}$$

||

$$\frac{|y|}{|x+y|} \quad \frac{|x|}{|x+y|}$$

$$\text{cond}_x(f_2) = \frac{|x| \cdot \frac{1}{x^2}}{\left|\frac{1}{x} - \frac{1}{y}\right|} = \frac{|y|}{|x-y|} \quad \left|\frac{1}{x} - \frac{1}{y}\right| = \frac{|xy|}{|x-y|}$$

$\therefore K \cap J / 3$

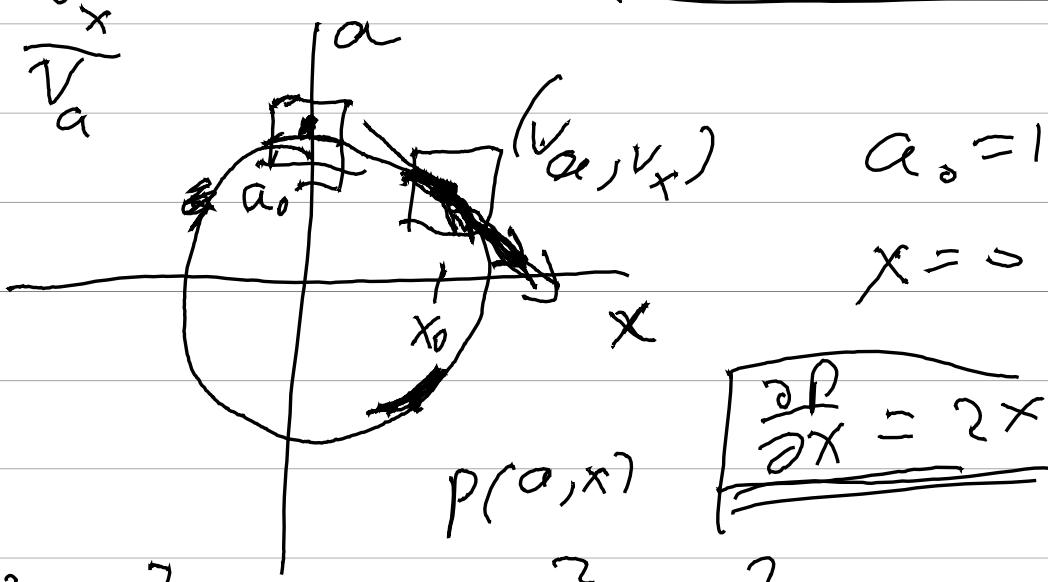


$h \rightarrow \infty ?$ $n' r > 1/p$

$$P_n(\bar{a}, X) = X^n + \sum_{i=0}^{n-1} a_i \cdot X^i$$

$$P_n(\bar{a}_0, \underline{x}_0) = 0 \quad x_0, \bar{a}^0$$

$$\approx F(x, y) = x^2 + y^2$$



$$a^2 + x^2 = 1$$

$$\underbrace{a^2 + x^2 - 1 = 0}_{\text{---}}$$

$$x = x(a)$$

$$x_0 = x(a_0)$$

$$x = \sqrt{1 - a^2}$$

$$P(a, x(a)) = 0$$

$$F(a, x) = 0$$



$$\underline{F(a_0, x_0) = 0}$$



$$\frac{\partial F}{\partial x}(a_0, x_0) \neq 0 \Rightarrow x = X(a)$$



$$\frac{\partial x}{\partial a} = \frac{\partial F}{\partial a} / \frac{\partial F}{\partial x}$$



$$df \cdot \begin{pmatrix} v_a \\ v_x \end{pmatrix} = 0$$

$$\begin{pmatrix} \frac{\partial f}{\partial a} & \frac{\partial f}{\partial x} \end{pmatrix} \begin{pmatrix} v_a \\ v_x \end{pmatrix} = 0$$

$$v_a \frac{\partial f}{\partial a} + v_x \frac{\partial f}{\partial x} = 0$$

$$X = X(\vec{a})$$

$$\text{cond}_{a_i}(x) = \frac{|a_i| \cdot \left| \frac{\partial X}{\partial a_i} \right|}{|x|} = \frac{|a_i| \cdot |f'(x)|}{|x| \cdot |P(x)|}$$

$$\frac{\partial X}{\partial a_i} = - \frac{\partial P / \partial a_i}{\partial P / \partial x} =$$

$$\frac{x^i}{\sum j a_j x^{j-1}} = \frac{x^i}{P'(x)}$$

$$\int_{-\infty}^{\infty} f(x) dx = \sum_{i=1}^n c_i \pi(a_i)$$

$$P(x) = (x-a_1) \dots (x-a_n)$$

인수분해법

$$f^*: \mathbb{R}^x \rightarrow \mathbb{R}^x \quad f: \mathbb{R} \rightarrow \mathbb{R}$$

$$f^*(x^*)$$

$$f(x)$$

$$x' \text{ 가 } x^* \text{ 인데 } f^*(x^*) = f(x') \text{ 인데}$$

$$\frac{|f^*(x^*) - f(x)|}{|f(x)|} = \frac{|f(x') - f(x^*) + f(x^*) - f(x)|}{|f(x)|} \leq$$

$$\frac{|f(x') - f(x^*)|}{|f(x)|} + \frac{|f(x^*) - f(x)|}{|f(x)|}$$
$$\frac{|f(x') - f(x^*)|}{|f(x)|} \approx \frac{|f(x') - f(x^*)|}{|f(x^*)|}$$

$$\underbrace{\text{cond}(f)(x^*)}_{\text{cond}(f)(x)} \cdot \boxed{\frac{|x' - x^*|}{|x^*|}}$$

f^* per i primi 3 m per

$$\text{cond}(f^*)(x^*) := \inf_{f(x') \neq f(x^*)} \frac{|x' - x^*|}{|x^*|}$$

$$\underbrace{\text{cond}(f)(x)}_{\text{cond}(f)(x^*)} \left(\frac{|x - x^*|}{|x|} + \text{cond}(f^*)(x^*) \right)$$

Definition \Rightarrow Definition \Rightarrow $f: X \rightarrow \mathbb{C}$

\Rightarrow $\exists \gamma$ $\exists \rho$ $f: X \rightarrow \mathbb{R}$
 $=$ \mathbb{C}

$\exists \delta$ $\forall n \in \mathbb{N}$ $\exists \rho$ $\forall n \in \mathbb{N}$
 $, \forall x \in X \exists \rho$

For $\forall \exists \gamma \forall n \in \mathbb{N} \exists \rho$ $\forall n \in \mathbb{N} A$

$\text{For } X \text{ "continuous" function }$

$\forall n \in \mathbb{N} \forall \gamma \exists \rho \forall n \in \mathbb{N} \exists \rho \forall n \in \mathbb{N} A$

$\forall \rho \forall \gamma \exists \rho \forall n \in \mathbb{N} A$

$X - \sim \rho \delta \gamma \exists \rho \forall n \in \mathbb{N} A = C(X)$

ר'ב גראן ב' נרנ'ן סט $P \subseteq A$

ר'ב גראן מושג

ר'ב גראן סט $P = \{x \mid f$

ר'ב גראן קבוצת סט $\underline{\underline{P}}$

$P = \{x \mid f(x) \in \text{הצורה}$

ר'ב גראן סט $f(A)$ ר'ב גראן סט

ר'ב גראן סט

$\{0,1\}$ ר'ב גראן סט $x = s'$

ר'ב גראן סט $0,1$ ר'ב גראן סט

$$f(x) = e^{2\pi i x} = \cos 2\pi x + i \sin 2\pi x \subseteq \mathbb{C}$$

'3' for each C for $\lambda \lambda \lambda \lambda \lambda \lambda \lambda$.

$$\text{Ansatz: } f(x) = \sin(2\pi n x) - 1 + \cos(2\pi n x)$$

$$\underbrace{\dots}_{(\Delta x \approx r_0)} \quad \text{hence}$$

$$\underbrace{\{e^{2\pi i n x}\}}$$

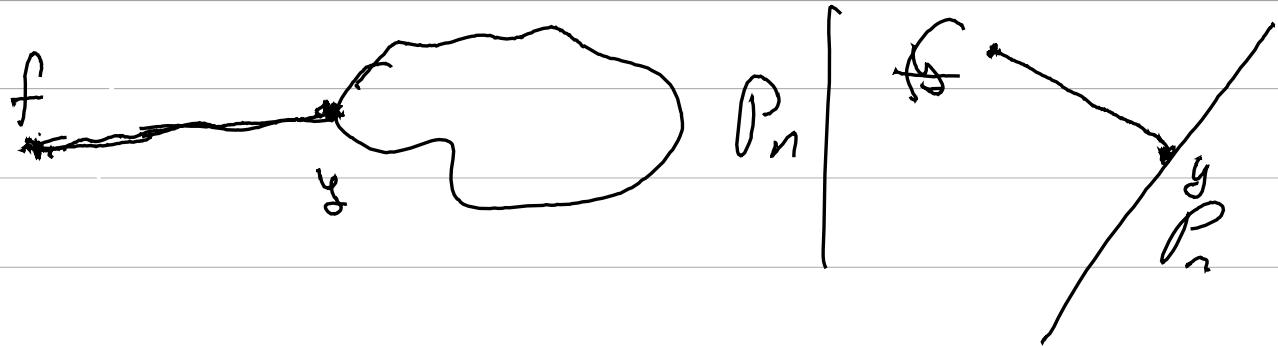
$$P = \bigcup P_i \quad P_0 \subseteq P_1 \subseteq P_2 \dots$$

3.2) 0 in N \Rightarrow f in P_n

$$n \in \mathbb{N} \quad \varepsilon > 0 \quad \text{such that } f \in P_n$$

$$\underbrace{d(f, P_n) < \varepsilon}_{\text{---}} \quad \text{---}$$

$$d(f, P_n) = \inf_{y \in P_n} d(f, y) = \inf_{y \in P_n} \|f - y\|$$



$\exists \delta > 0 \forall \epsilon' \exists C(x) \text{ for}$

$\|f\|_{C(X)} < \infty$

$$\|f\| = \sup_{x \in X} |f(x)| < \infty$$

$\|f\|_{C(X)} \leq \sup_{x \in X} |f(x)| + \|C_0\|_{C(X)}$

$\forall M > 0 \exists \delta > 0 \forall x, y \in X \quad |f(x) - f(y)| \leq M$

($\forall x, y \in X \exists \delta > 0 \forall z \in X \quad |f(z) - f(x)| < \delta \Rightarrow$

$f \in P \quad \forall x, y \in X \quad x \neq y \Rightarrow f(x) \neq f(y)$

$\exists \delta > 0 \forall x, y \in X \quad |x - y| < \delta \Rightarrow f(x) \neq f(y)$

$f: X \rightarrow \mathbb{R}$ $\exists \delta > 0 \forall x, y \in X \quad |x - y| < \delta \Rightarrow |f(x) - f(y)| < \epsilon$

$\exists \delta > 0 \forall x, y \in X \quad |x - y| < \delta \Rightarrow |f(x) - f(y)| < \epsilon$

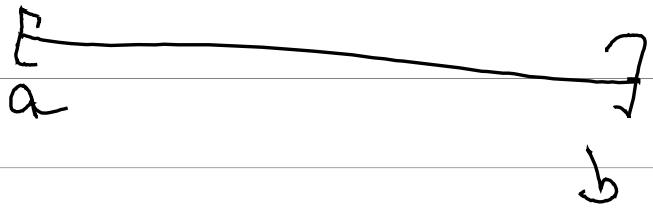
$\exists \delta > 0 \forall x, y \in X \quad |x - y| < \delta \Rightarrow |f(x) - f(y)| < \epsilon$

$C(x) \ni f \in \mathcal{D} \Leftrightarrow C(x) - \mathcal{D} \ni e^f \in \mathcal{P}$

→) P(P) e' {> 0 5 f)

$$\|f - p\| < \varepsilon$$

If $|f(x) - p(x)| < \varepsilon$ for all x in I



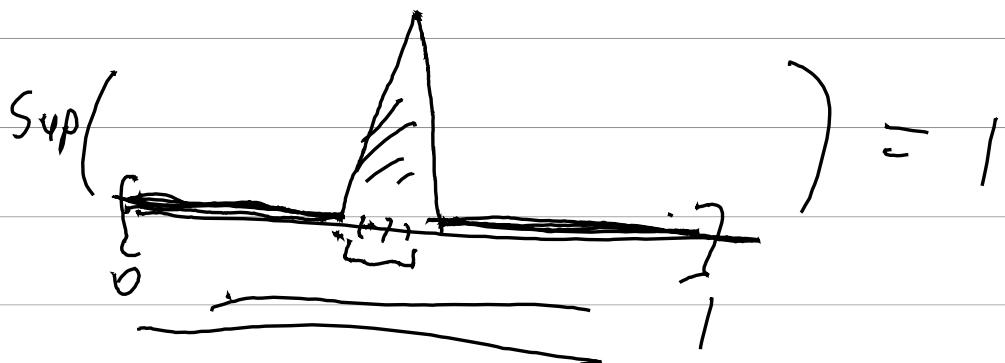
מִתְּבָאֵר בְּבָאָה כַּאֲמָר

ପ୍ରାଚୀ ମହିଳା କାନ୍ଦିଲ

22' 3" 22' 3" 11' 5" : 1cr d / 3
2' 4" 22' 5" 20' 1" for n, 1

הנורמליזציה

הו



$\|\cdot\|_p \rightarrow \cup \quad 1 \leq p \leq \infty \quad \int_{\mathbb{R}^n}$

$$\|\bar{x}\|_\infty = \max(|x_i|)$$

$$\|\bar{x}\|_p = \sqrt[p]{\sum |x_i|^p} \quad 1 \leq p < \infty$$

$x \in \mathbb{R}^n$
 $\|\cdot\|_\infty$ $\|\cdot\|_p$

ונורמליזציה

$\mathbb{R}^n \rightarrow \text{הנורמליזציה} \subset \text{הנורמליזציה}$

$\| \cdot \|_2 : C(X) \rightarrow \mathbb{R}$??

$(L_2, \|\cdot\|_2)$?

$$\|f\|_2^2 = \int_X |f|^2$$

$\therefore \rho(F) \approx \underbrace{X = \{1, 2, \dots, n\}}$ AC

类似地 L_2 与 \mathbb{C}^n

类似地 L_2 与 \mathbb{C}^n

类似地 $\omega : X \rightarrow \mathbb{R}$ 定义

$$\|f\|_{\omega, 2} = \sqrt{\int_X |f|^2 \cdot \omega}$$

$$\|f\|_2^2 = \int_X |f|^2 \leq \sup_X |f|^2 \cdot \left[\int_X 1 \right] =$$

$$\|f\|_\infty^2$$



$\hookrightarrow \text{Naturale } \text{ und } \text{ reelle } \text{ Zahlen}$

$\sim \text{wegen } \text{ Gitter}$

$X \quad f: X \rightarrow \mathbb{R}$

$$A \subseteq X \quad 1_A(x) = \begin{cases} 1 & x \in A \\ 0 & x \notin A \end{cases}$$



نیز پس از اینجا $\sum_{x \in X} f(x)$ را

(\rightarrow زیرا $\sum_{x \in X}$)

$$f: X \rightarrow \mathbb{R}$$

$$\underbrace{\int_X f}_{\sum_{x \in X} f(x)}$$

$$X = \{1, \dots, n\}$$

$$f: X \rightarrow \mathbb{R} \Leftrightarrow \text{دایا}$$

$$\|f\|_p = \sqrt[p]{\sum_{i=1}^n |f_i|^p}$$

لذا $\|\int f\|$ را نمایند V را

V بر $\underbrace{\mathcal{P}(V)}$ را فرموده باشند، $k = \mathbb{R}$ را

$\langle \cdot, \cdot \rangle: V \times V \rightarrow k$ را فرموده باشند

$v \mapsto \langle v, u \rangle$ 'ər , $u \in V$ ֆ . 1

$\underline{\langle u, v \rangle := \overbrace{\langle v, u \rangle}}$, $u, v \in V$ ֆ . 2

$\langle u, u \rangle \in \mathbb{R}$, $u \in V$ ֆ $S(c)$

$\langle u, u \rangle > 0$ ՏՇ $u \neq 0$ ա՛ւ . 3

V հայելա բազու ՀՇ $\langle \cdot, \cdot \rangle$ ա՛ւ

$v \mapsto \|v\| := \sqrt{\langle v, v \rangle}$ ՀՇ պահանջ ս՛կ

. V հայելա բազու ՀՇ

$u, v \in V$ բազու , հարաբեր աղյօնա

$\|u+v\|^2 = \langle u+v, u+v \rangle = \langle u, u \rangle + 2\langle u, v \rangle + \langle v, v \rangle$

$\|u\|^2 + \|v\|^2 + \underline{2\langle u, v \rangle}$

הנ'יה יסוד נורמליזציה

מכפלה סקלרית

$$\frac{\|u+v\|^2 - \|u\|^2 - \|v\|^2}{2} \leftarrow (u, v)$$

הנ'יה יסוד נורמליזציה

הנ'יה יסוד נורמליזציה, $\rho = 2$ מילר

הנ'יה $C(x)$ גורם

$$(u, v) \mapsto \int_X u \cdot v$$

הנ'יה יסוד נורמליזציה

הנ'יה יסוד נורמליזציה
 $\langle u, v \rangle = 0$ מילר u, v

$\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_n$ $\sqrt{\lambda}$

$\sqrt{\lambda}$

$$\left\| \sum a_i v_i \right\|^2 = \sum a_i^2 \|v_i\|^2$$

(Eigenvalues are the singular values)

$\sqrt{\lambda_1} \geq \sqrt{\lambda_2} \geq \dots \geq \sqrt{\lambda_n}$

$P = U P' \quad -1, X \text{ for } \sqrt{\lambda} \text{ diag}$

Matrix diagonalization, eigenvalues

Eigenvalues are the singular values

$$[\sqrt{\lambda_1} \mid \sqrt{\lambda_n}] \quad \underline{P_n - \delta} \quad \{ \pi_i \}$$

$f \in A$

$$T(c_1, \dots, c_m) = \|f - \sum c_i \pi_i\|^2 = \langle f - \sum c_i \pi_i, f - \sum c_i \pi_i \rangle =$$

$$\|f\|^2 - 2 \underbrace{\sum c_i \langle f, \pi_i \rangle}_{\text{underlined}} + \sum c_i c_j \langle \pi_i, \pi_j \rangle$$

Suppose T is a linear operator

such that $\sum c_i \pi_i$ is in the range of T

$$\cdot 0 \quad \int \pi_i c_i \rightarrow \int \pi_i$$

$$0 = \frac{\partial T}{\partial c_k} = -2 \langle f, \pi_k \rangle + 2 \sum c_j \langle \pi_k, \pi_j \rangle$$

$$\sum c_j \langle \pi_k, \pi_j \rangle = \langle f, \pi_k \rangle$$

$\|f\|$ is the norm of f

$$A \tilde{c} = b$$

$$b_i = \langle f, \pi_i \rangle \quad \in \mathbb{C}$$

$$A = (\langle \pi_i, \pi_j \rangle)_{i,j}$$

$$\lambda_1, \lambda_2, \dots, \lambda_n \in C_n^{\perp} \quad \text{and} \quad A$$

$$(x, y) \mapsto \underline{\langle x, Ay \rangle} \leftarrow \begin{matrix} \mathbb{R}^n \times \mathbb{R}^m \\ \text{from } \mathbb{R}^m \end{matrix}$$

$$S \subset \tilde{X} \neq \emptyset \quad \text{and}, \quad \text{with}$$

$$\underline{\tilde{x} \cdot A \tilde{x}} \geq 0$$

$$\tilde{x} \cdot A \tilde{x} = \sum_{i,j} x_i x_j \langle \pi_i, \pi_j \rangle = \underline{\|\sum x_i \pi_i\|^2}$$

$$\tilde{x} \neq 0 \quad \text{if} \quad \{x_i \pi_i\} \neq \{0\} \quad \text{and} \quad \{\pi_i\}$$

i) $\mu\sigma$ $\Rightarrow \sigma \text{ is } A$, $\exists \omega$
 $\sigma \text{ is not } f(\omega)$

$$(\pi_i)_{i \geq 0}$$

$$A = \left(\begin{matrix} \langle \pi_i, \pi_j \rangle \end{matrix} \right)_{1 \leq i, j \leq n}$$

$$A \bar{c} = b \quad \bar{c} = \langle f, \pi_i \rangle$$

$$[0, 1] \quad \text{for} \quad \pi_i = t^{\frac{i}{n}} \underbrace{[t^n, 1]}$$

$$\langle f, g \rangle = \int_0^1 f \cdot g \, dt$$

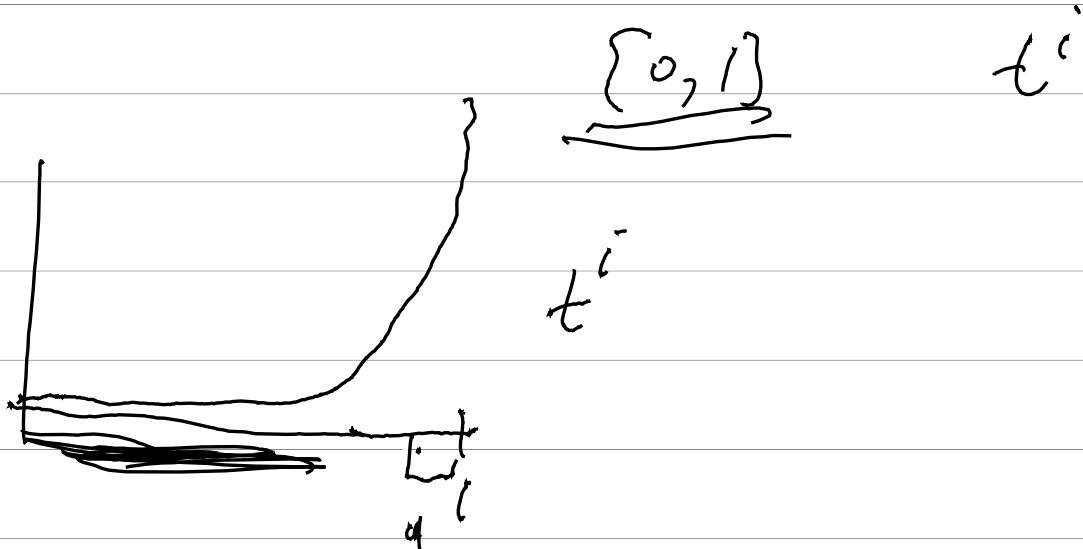
$$\langle \pi_i, \pi_j \rangle = \int_0^{t^{\frac{j}{n}}} t^{\frac{i}{n}} \, dt = \frac{t^{\frac{i+j+1}{n}}}{\frac{i+j+1}{n}} \Big|_0^1 =$$

$$H_3 = \begin{pmatrix} 1 & \frac{1}{2} & \frac{1}{3} \\ \frac{1}{2} & \frac{1}{3} & \frac{1}{1} \\ \frac{1}{3} & \frac{1}{1} & \frac{1}{2} \end{pmatrix}$$

$H_n C = I$ \Rightarrow $C^{-1} = H_n$

\Rightarrow C^{-1} \rightarrow def matrix \Rightarrow 3×3

$C^{-1} \rightarrow$ def matrix and def matrix



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: ($\sum_{i=1}^n \pi_i / n - 1/n$) $\leq \mu / n < 1/n$

$$\langle \pi_i, \pi_j \rangle = 0 \quad i \neq j \quad (\langle \pi_i, \pi_i \rangle = 1)$$

$$f = \sum a_i \pi_i$$

$$\underbrace{\langle f, \pi_i \rangle = a_i \langle \pi_i, \pi_i \rangle}$$

π_1, π_2, \dots

$\sum \pi_i / n \leq 1/n$

$$\hat{\pi}_i = \pi_i$$

$$\hat{\pi}_{k+1} = \pi_{k+1} - \sum \left(\frac{\hat{\pi}_{k+1}}{\hat{\pi}_i} \right) \frac{\hat{\pi}_i}{\sqrt{\hat{\pi}_i}} \hat{\pi}_i$$
$$\langle \hat{\pi}_{k+1}, \hat{\pi}_i \rangle = \left(\sum_{i=1}^{k+1} \hat{\pi}_i \right) \frac{1}{\sqrt{\hat{\pi}_i}} \langle \hat{\pi}_{k+1}, \hat{\pi}_i \rangle = 0$$

$$P = \bigcup P_i \quad P_0 \subseteq P_1 \subseteq \dots$$

$$P_i = \left\{ i \geq \frac{\epsilon \sqrt{N} \sum S_j}{\delta} \right\}$$

$$\dim(P_i) = i$$

$$\text{Span}(\langle \pi_i \rangle_{i \leq v}) = \text{Span}(\langle \hat{\pi}_i \rangle_{i \leq v})$$

$$\hat{\pi}_i \in P_i \quad | \quad \text{plan } p(j|s)$$

$$\hat{\pi}_{i+1} = t \hat{\pi}_i - \alpha_i \hat{\pi}_i + \sum_{j=0}^{i-1} b_j \hat{\pi}_j =$$

$$(t - \alpha_i) \hat{\pi}_i + \beta_i \cdot \hat{\pi}_{i-1} + \sum_{j=0}^{i-2} b_j \hat{\pi}_j$$

$$\langle \hat{\pi}_{i+1}, \hat{\pi}_i \rangle = \langle (t - \alpha_i) \hat{\pi}_i, \hat{\pi}_i \rangle \Rightarrow$$

$$\alpha_i \cdot \| \hat{\pi}_i \|^2 = \langle t \hat{\pi}_i, \hat{\pi}_i \rangle$$

$$\Rightarrow \alpha_i = \frac{\langle t\hat{\pi}_i, \hat{\pi}_i \rangle}{\|\hat{\pi}_i\|^2}$$

$$0 = \underbrace{\langle (t - \gamma_i) \hat{\pi}_i, \hat{\pi}_{i-1} \rangle}_{\beta_i \cdot \|\hat{\pi}_{i-1}\|^2} +$$

$$\beta_i = - \frac{\langle t\hat{\pi}_i, \hat{\pi}_{i-1} \rangle}{\|\hat{\pi}_{i-1}\|^2} =$$

$$- \frac{\langle \hat{\pi}_i, t\hat{\pi}_{i-1} \rangle}{\|\hat{\pi}_{i-1}\|^2} = - \frac{\|\hat{\pi}_i\|^2}{\|\hat{\pi}_{i-1}\|^2}$$

$$\hat{\pi}_{i+1} = (t - \gamma_i) \hat{\pi}_i + \underbrace{\beta_i \hat{\pi}_{i-1}}$$

For a more rigourous view see

$[-a, a]$ $\rightarrow \mathbb{R}^n$ \rightarrow L^2

$w(t) = w(t, t)$ \wedge C^0 $f(t)$ \rightarrow \mathbb{R}^n , t

$$\left[\langle f, g \rangle = \int_a^b f(t) \overline{g(t)} w(t) dt \right]$$

we say $\int f$ is π_k if

if $\|f\|_k \leq 1$ $\forall k$

$\mathcal{L}^k = 0$ \Rightarrow $\int f$

Real $\{-1, 1\}$ $\rightarrow \mathbb{C}^2$ is \mathcal{L}^k

$(\int f)^2 \leq \|f\|_k^2$ \Rightarrow $\int f$

$$T_n(t) = \underbrace{\frac{k!}{(2k)!}}_{\text{constant}} \frac{d^k}{dt^k} (t^2 - 1)^k$$

$$(\ln/(t - \pi_k) - e^{-\sqrt{t}}) \int \dots$$

从 π_k 到 t^k , 令 t^k 为 π_i 的

$$0 = \langle \pi_k, t^i \rangle = \int_{-1}^1 \frac{d^k}{dt^k} (t^2 - 1)^k \cdot t^i dt =$$

$$\dots = 0$$

$$\pi_0 = 1, \quad \pi_1 = \frac{1}{2}(t^2 - 1)' = t$$

$$\pi_2 = ((t^2 - 1)^2)' \cdot \frac{2}{4!} = \frac{1}{12} \cdot ((t^2 - 1)^2)''$$

$$\pi_k = \underbrace{t^k + \mu_k t^{k-2} + \dots}$$

$$\pi_{k+1} = t \cdot \pi_k + \beta_k \cdot \pi_{k-1} \Rightarrow \boxed{\beta_k = \frac{\pi_{k+1} - t \pi_k}{\pi_{k-1}}}$$

$$\beta_k = \mu_k - \mu_{k+1}$$

$$\mu_k = \frac{k(k-1)}{2(2k-1)} \Rightarrow$$

$$\beta_k = \frac{1}{4-k^2}$$

Wichtigste Ergebnisse

if $\alpha \sim \pi$ then β

$$\underline{f: \mathbb{R} \rightarrow \mathbb{R}} \quad f(f+f) = f(\cancel{f})$$

↓ . t ↗

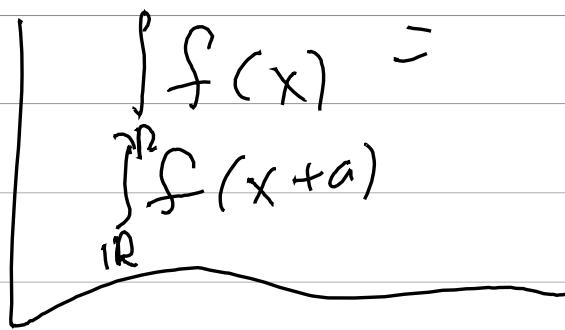
$$f: [0,1] \rightarrow \mathbb{R} \quad f(0) = f(1)$$

$$(\sin(2\pi t) + \cos(2\pi t)) = \underline{\underline{e^{2\pi i t}}}$$

(=)

$$g: \mathbb{S}' \rightarrow \mathbb{C}$$

$$\mathbb{S}' = \{ z \in \mathbb{C} \mid |z| = 1 \}$$



$$E: [0,1] \rightarrow \mathbb{S}'$$

$$E(t) = e^{2\pi i t}$$

$$g: \mathbb{S}' \rightarrow \mathbb{C} \rightsquigarrow g \circ E \text{ - convolution }$$

$$\int_{\mathbb{S}'} g := \int_0^1 g \circ E dt$$

$$z, w \in \mathbb{S}' \quad \text{if } z, w \in \mathbb{S}' \quad \text{no!}$$

For formal $a \in \mathbb{S}'$ \rightsquigarrow

$$g_a(z) = g(a \cdot z)$$

$$\int_{\mathbb{S}'} g_a = \int_{\mathbb{S}'} g \quad \text{sic}$$

$g : S' \rightarrow \mathbb{C}^*$ $\rightsquigarrow r'/\mathbb{H}$ \mathbb{H}/\mathbb{C}

$g(z \cdot w) = g(z) \cdot g(w)$ $\rightsquigarrow \mathbb{H}' \supset \mathbb{N}$

z für $g(z) = 1$ \mathbb{H}/\mathbb{C} S/\mathbb{C}

$\int_S g = 1$ S/\mathbb{C}

$\int_S g = 0$ $\mathbb{H}/\mathbb{C} \rightarrow$

→ \mathbb{H}/\mathbb{C}'

$g(a) \neq 1 \quad \text{e. } \quad a \in S' \quad e' \cdot \omega$

$g_a(x) = g(ax) = g(a) g(x)$

$\int_S g = \int_S g_a = \int_S g(a) \cdot g = \underbrace{g(a)}_{\neq 1} \int_S g$ S/\mathbb{C}

$\int_S g = 0$ S/\mathbb{C}

$$g_n(x) \approx x^n \quad \text{for } n \in \mathbb{Z} \quad \text{def}$$

or \approx in $\mathcal{O}(x)$ we have x^n

$$\overline{g_n(x)} = g_{-n}(x) \quad g_n \cdot g_m = g_{n+m}$$

\approx $\mathcal{O}(x)$ \Rightarrow $\mathcal{O}(x)$ \approx $\mathcal{O}(x)$

$$\approx \mathcal{O}(s) \quad \square$$

$$\langle f, g \rangle = \int_{S^1} f, \bar{g}$$

\approx $\mathcal{O}(s)$ \Rightarrow $\mathcal{O}(s)$

$$\approx \mathcal{O}(s)$$

\approx $\mathcal{O}(s)$ \Rightarrow $\mathcal{O}(s)$

$$\langle \mathcal{O}(s), \mathcal{O}(s) \rangle \approx \mathcal{O}(s) \quad \text{def}$$

$\rho' \cap \cup_{j=1}^m \sigma_j$ is a disjoint set

$\rho' \cap C \cap \cup_{j=1}^m \sigma_j$

$$c = \int_0^1 x^n = \int e^{2\pi i n t} dt = \int_{\gamma} e^{2\pi i n t + i \frac{2\pi}{n} t^2} dt$$

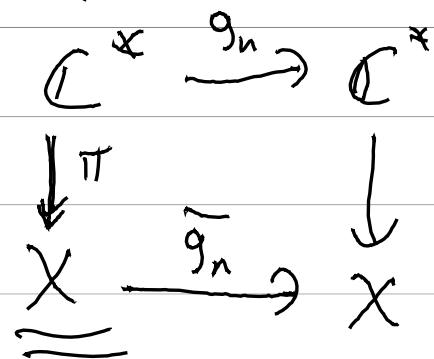
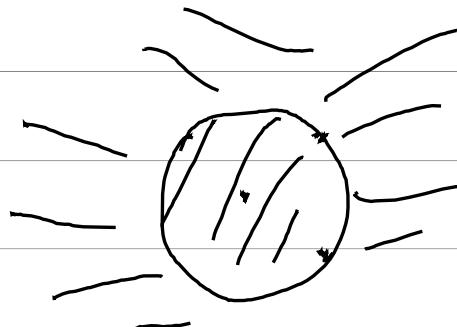
$\therefore f(z) \neq$

$$\mathbb{C}^* = \{z \in \mathbb{C} \mid z \neq 0\}$$

If $x=y$ $\Rightarrow \mathbb{C}^*$ $\neq \mathbb{C}$

$$x = \frac{x}{y}$$

$$g_n(x) = \frac{1}{x^n} \sim x^n \Rightarrow x = \frac{1}{g_n(x)}$$



$$\pi(x) = x + \frac{1}{x} \in \mathbb{C}$$

$$\pi(x) = \pi\left(\frac{1}{x}\right)$$

$$\begin{aligned} & \text{for } z \in \mathbb{S}' \text{ in } \mathbb{H}_C \\ \pi(z') &= \operatorname{Re}(z) \\ \pi(S') &= [-1, 1] = X_C \end{aligned}$$

$$g_n\left(\frac{x + \frac{1}{x}}{2}\right) = \frac{x^n + \frac{1}{x^n}}{2} = \pi(g_n(x))$$

thus X is in \mathbb{H}_C

$$\star \int_{X_0}^X h = \int_{S'} h \circ \pi = \int_{S'} h\left(\frac{x + \frac{1}{x}}{2}\right)$$

$$\int_0^1 h(\operatorname{Re}(e^{2\pi i t})) dt = \int_0^1 h(\cos(2\pi t)) dt$$

$$y = \cos(2\pi t) \quad dy = 2\pi \sin(2\pi t) dt =$$

$$dy = -2\pi \sqrt{1-y^2} dt$$

$$x = \int_{-1}^1 h(y) \frac{1}{\sqrt{1-y^2}} dy$$

~~\int_0^1~~

Integrals \rightarrow $\widehat{g}_n \rightarrow x$

now we have $\int_{-1}^1 f g \frac{1}{\sqrt{1-y^2}} dy$

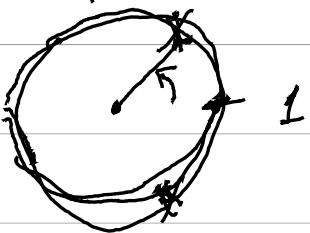
$\int_{-1}^1 f g \frac{1}{\sqrt{1-y^2}} dy$ $\sim \int_{-1}^1 f g dy$

$$\langle f, g \rangle = \int_{-1}^1 f \cdot g \frac{1}{\sqrt{1-y^2}} dy$$

~~\int_{-1}^1~~

$$\widehat{g}_n (\cos 2\pi n t) = \underbrace{\cos 2\pi n t}$$

$$S^1 = \{ z \in \mathbb{C} \mid |z| = 1 \}$$



$\downarrow P$

$$\sin 2\pi t = \sqrt{1 - y^2}$$

$$0 \leq t \leq \frac{1}{2}$$

$$[\leftarrow]_x = [-1, 1] \subset \mathbb{R}$$

x

$$p(z) = \frac{z + \bar{z}}{2} (= \frac{z + \bar{z}}{2} = \operatorname{Re}(z)) \quad S'$$

$$f : X \rightarrow \mathbb{C}$$

$$y = \cos 2\pi t$$

$$dy = -2\pi \sin 2\pi t dt$$

$$\int_X f := \int_{S^1} f \circ p = \int_0^1 f \circ p \circ e^{2\pi i t} dt =$$

$\frac{1}{2}$

$$\int_0^1 f(\cos 2\pi t) dt = 2 \int_0^{\frac{1}{2}} f(\cos 2\pi t) dt =$$

$$2 \int_{-1}^1 f(y) \cdot \left(-\frac{1}{2\pi}\right) \frac{dy}{\sqrt{1-y^2}} =$$

$S' \xrightarrow{\varphi_n} S'$

$\varphi_n(x) = x^n$

$$T_n\left(\frac{x+\frac{1}{x}}{2}\right) = \underbrace{x^n + \frac{1}{x^n}}_2$$

$$\int_X T_n = \int_{S'} T_n \circ \varphi = \int_{S'} \underbrace{x^n + \frac{1}{x^n}}_2 =$$

~~$\int_X T_n = \int_{S'} T_n \circ \varphi = \int_{S'} x^n + \frac{1}{x^n} =$~~

$$\begin{cases} 1 & h=0 \\ 0 & h \neq 0 \end{cases} \quad \begin{cases} \int_{S'} \varphi_n \bar{\varphi}_m = \\ \int \varphi_n \varphi_{n+m} = \int \varphi_{n-m} \end{cases}$$

$$(T_n \cdot T_m) \left(\frac{z + \frac{1}{z}}{2} \right) = \underbrace{\left(z^n + \frac{1}{z^n} \right)}_{2} \left(\frac{z^m + \frac{1}{z^m}}{2} \right).$$

$$\frac{1}{2} \underbrace{\left(z^{m+n} + \frac{1}{z^{m+n}} + z^{n-m} + z^{m-n} \right)}_{2} =$$

$$\frac{1}{2} \left(T_{n+m} \left(\frac{z + \frac{1}{z}}{2} \right) + T_{n-m} \left(\frac{z + \frac{1}{z}}{2} \right) \right)$$

$$\int T_n \cdot T_m = \frac{1}{2} \left(\int T_{n+m} + \int T_{n-m} \right) =$$

$$\int \begin{cases} \frac{1}{z} & n = m \neq 0 \\ 1 & n = m = 0 \\ 0 & (n \neq m) \end{cases} \int T_n = T_{-n}$$

$$T_0 = 1 \quad T_0\left(\frac{z + \frac{1}{z}}{2}\right) = 1$$

$$T_1\left(\frac{z + \frac{1}{z}}{2}\right) = z + \frac{1}{z} \quad T_1(z) = z$$

$$T_n \cdot T_1 = \frac{1}{2} (T_{n+1} + T_{n-1}) \Rightarrow$$

$$T_{n+1}(z) = 2z T_n(z) - T_{n-1}(z)$$

$$T_2(z) = 2z^2 - 1$$

$$\cos(2t) = 2(\cos^2 t - 1)$$

$$\cos(\alpha t) = T_n(\cos t)$$

$$\text{For } \rho \geq 1, \text{ in } \mathbb{C}^{2^n} \text{ with } T_n \in \mathbb{Z}^n$$

3) $\lim_{n \rightarrow \infty} f_n(x)$

f 3) $\lim_{n \rightarrow \infty} f_n(x)$

$\lim_{n \rightarrow \infty} f_n(x) = 0$ $\forall x \in \mathbb{R}$

$c_0, \dots, c_n \in [a, b] \subseteq \mathbb{R}$

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$\lim_{n \rightarrow \infty} f_n(x) = 0$ $\forall x \in \mathbb{R}$

c_0, \dots, c_n für $f(x) = \sum_{i=0}^n a_i x^i$

0, 1, ..., n+1 \Rightarrow a_0, a_1, \dots, a_n

$$f_i(c_j) = \begin{cases} 1 & j=i \\ 0 & j \neq i \end{cases}$$

$$P_i(x) = \frac{\prod_{j \neq i} (x - c_j)}{\prod_{j \neq i} (c_i - c_j)} \in P_n = \text{Span } \{1, x, x^2, \dots, x^n\}$$

$$f(c_i) = f_i \Rightarrow$$

$$f \sim \underbrace{\sum f_i l_i}_{=} = \pi_{\tilde{C}}(f)$$

$$\pi_{\tilde{C}} : C[a,b] \rightarrow C[a,b]$$

$$\sup_{\|f\|=1} \|\pi_{\tilde{C}}(f)\| = \sup_{\|f\|=1} \left\| \sum f_i l_i \right\| =$$

$$= \sum_{i=0}^n \|l_i\|$$

$$\lambda_n(x) = \sum_{i=0}^n |l_i(x)|$$

$$f - \underbrace{f - \pi_C(f)}_{\text{orthogonal projection}} \rightarrow f - \hat{P}_n$$

$$\|P_n - \cdot\|$$

$$\|\underbrace{f - \pi_C(f)}_{\text{orthogonal projection}}\| = \|f - \hat{P}_n - \pi_C(f - \hat{P}_n)\|$$

$$\leq \|f - \hat{P}_n\| + \|\pi_C\| \|f - \hat{P}_n\| =$$

$$\underbrace{\left(1 + \|\pi_C\|\right)}_{\text{constant}} \|f - \hat{P}_n\|$$

برهان انتقالی

$$\begin{aligned} & C^{n+1}[a, b] \ni f \\ & (f - \pi_C(f))(x) = \underbrace{\frac{f^{(n+1)}(\xi)}{(n+1)!} \prod_{i=0}^n (x - c_i)}_{\text{polynomial}} \end{aligned}$$

$(x \rightarrow i\beta_n)$
 $\cup / \gamma/\approx \cup \{ e' : \approx \subseteq$

$(f \in C^{n+1}[a, b]) \quad | \cup$

$c_i \neq x \quad x \geq c_i \quad \underline{i \geq n+1}$

$G(t) = \underbrace{f(t) - \pi_{\mathcal{E}}(f)(t)}_{= 0} -$

$$\frac{f(x) - \pi_{\mathcal{E}}(f)(x)}{\prod_{i=0}^n (x - c_i)} = \frac{n}{\prod_{i=0}^n (t - c_i)}$$

マトリクス $\Rightarrow G$ の $n+1$ 次

$x - 1 \quad i=0, \dots, n \quad c_i$

$G^{(n+1)}$
 $-f : \mathbb{R} \rightarrow \mathbb{C}$
 $\cdot \{ \quad \text{オーバー} \quad e'$

ו'נ'ג = $n+1$ (∞) $\cap \mathcal{S}_{\rho}$

$$G^{(n+1)}(t) = f^{(n+1)}(t) - (n+1)! \cdot \frac{f(x) - f(t)}{\prod_{i=1}^n (x - c_i)}$$

$t = \zeta$ $\omega_{\lambda} \varphi$

$\zeta \in [a, b]$

$[a, b] \rightarrow \cup_{\lambda} \mathcal{S}_{\rho}$

(x, c_i) \square $\cap \mathcal{S}_{\rho}$

$$\int_{C(3)} \int_{\gamma_0} f \underbrace{d\gamma}_{{}^{\text{def}} \gamma'}$$

$$= \int_{\gamma_0} f \circ \tilde{\gamma} \in \mathbb{C}^{(n)}_{\gamma_0}$$

$$= \int_{\gamma_0} f \circ \tilde{\gamma} = \int_{\gamma_0} f \circ \tilde{\gamma} \circ \tilde{\gamma}'$$

$$\pi_{C^{(n)}}(f) \rightarrow f$$

$$\int_{\gamma_0} f \circ \tilde{\gamma} = \int_{\gamma_0} f$$

$$\pi_{C^{(n)}}(f)$$

$$\|f - \pi_{C^{(n)}}(f)\| \leq \left\| \frac{f^{(n+1)}(\xi)}{(n+1)!} \right\|_{C^{(n)}} \|x - c_i^{(n)}\|$$

$$\leq \frac{m_{n+1}(f)}{(n+1)!} \cdot (b-a)^{n+1}$$

$$\boxed{[a,b] \ni f \text{ has } m_{n+1}(f) \text{ small}}$$

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$$\frac{m_n(f) \cdot (b-a)^n}{n!} \rightarrow 0$$

$c_i \in [a, b]$ γ' 3 מינימום של m_{n+1} ב-

$$\|f - \pi_{\bar{c}}(f)\| \leq \left\| \frac{f^{(n+1)}(\xi)}{(n+1)!} \cdot \prod_{i=1}^n (x-c_i) \right\|$$
$$\leq \frac{m_{n+1} \cdot (b-a)^{n+1}}{(n+1)!}$$

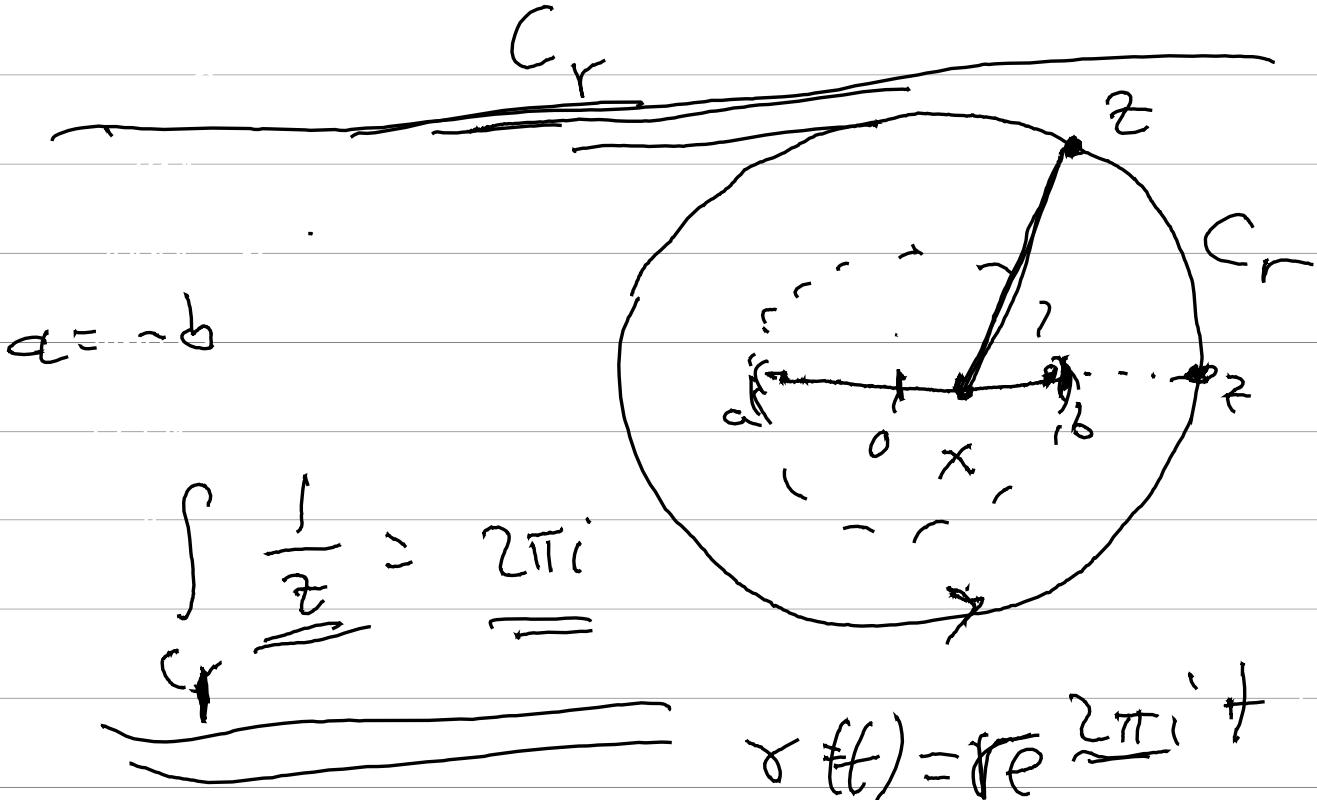
$$m_n = \|f^{(n)}\|_{\infty}$$

ר' סיסיק גאנז לנ' א' f

$\text{Rückgrat f. der : } \ell \rightarrow \text{nach}$

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$$f^{(k)}(x) = \frac{k!}{2\pi i} \oint \frac{f(z)}{(z-x)^{k+1}} dz$$



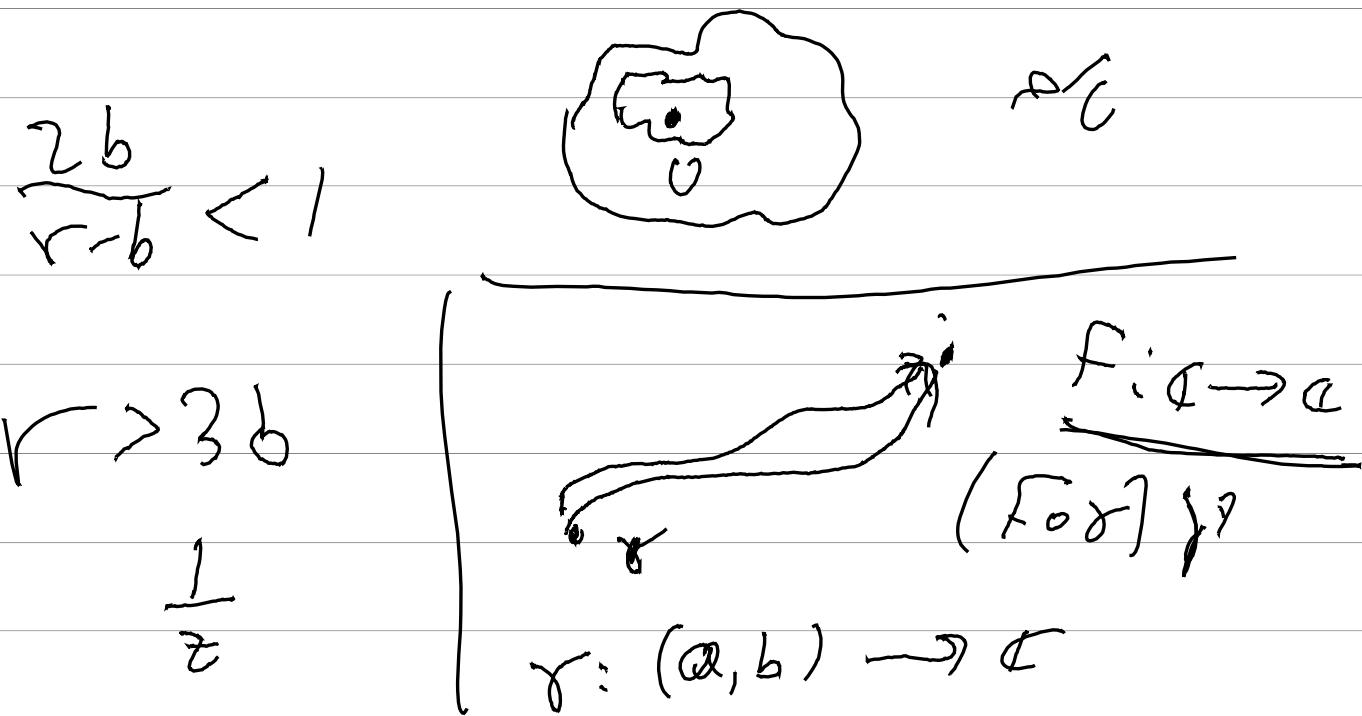
$$\underbrace{\|z-x\|}_{\geq r-b}$$

$$\|f^{(k)}(x)\| \leq \frac{k!}{2\pi} \frac{M_N}{(r-b)^{k+1}} \cdot 2\pi r \Rightarrow$$

$$\frac{M_n \cdot (2b)^n}{n!} \leq \frac{n! \cdot M_0}{(r-b)^{n+1}} \cdot r \cdot (2b)^n =$$

$n!$

$$\frac{M_0 \cdot r}{r-b} \cdot \left(\frac{2b}{r-b}\right)^n \rightarrow 0$$



רְאֵבָן | פְּלִינְהָן אֶלְגַּיְלָן
 $([-1, 1])$ ס) || • 160 גוֹדְרָה נ

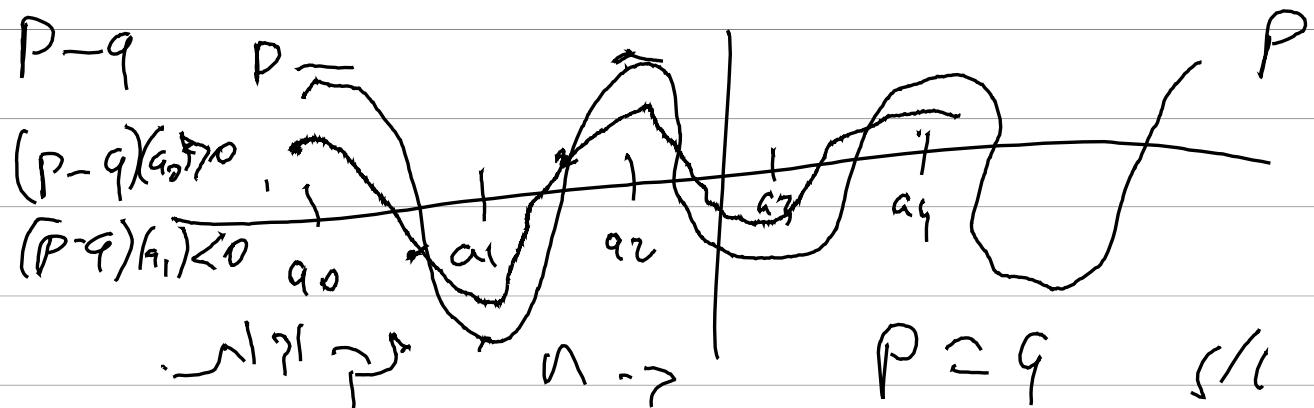
? גְּדוּלָה מ'

רְאֵבָן | פְּלִינְהָן אֶלְגַּיְלָן P אֶלְגַּיְלָן

ולא $\|P\|_\infty = |P(a_i)|$ \rightarrow n
 $P(a_i) = -P(a_{i+1})$
 P ס) a_i a_i $\rightarrow P$ n+1

רְאֵבָן $\|P\|_\infty$ וְאֶלְגַּיְלָן ח'נ

$\|q\| < \|p\| \Rightarrow$ א'ל, יונק



Complex numbers in polar form

input x \mapsto \sim^n

$$T_n(\operatorname{Re} z) = \underbrace{\operatorname{Re}(z^n)}$$

$$\Rightarrow T_n(x) = 0$$

$$\text{nc } z^n$$

\Leftrightarrow

$$x = \cos\left(\pi \frac{2k+1}{2n}\right)$$

$$z^n = \pm i$$

$$y = \cos\left(\pi \frac{k}{n}\right)$$

$$z^n = i \Leftrightarrow$$

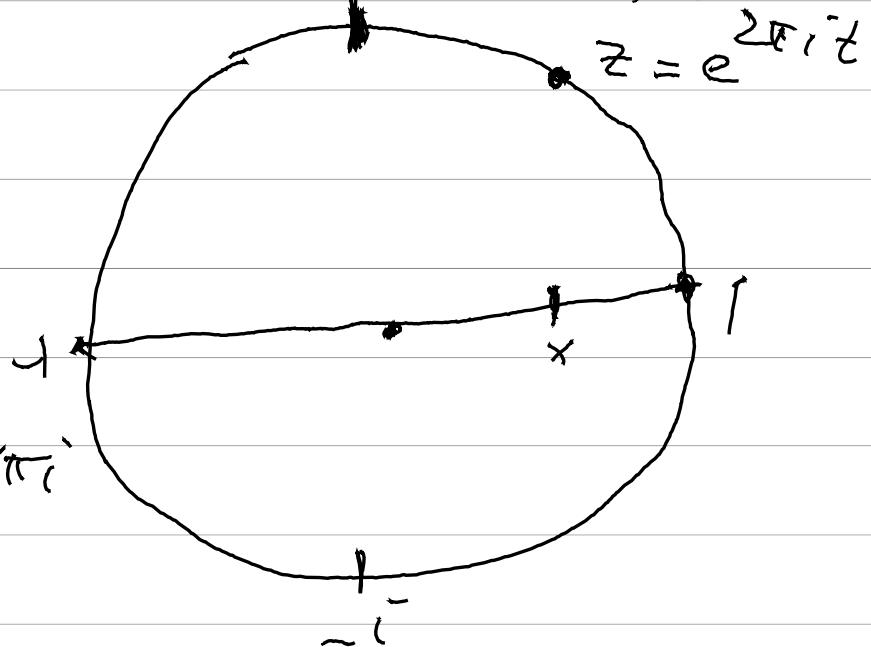
$$k=0, \dots, n$$

$$z = e^{2\pi i \frac{k}{n}}$$

$$e^{2\pi i \operatorname{int}} = i$$

$$2\pi i \operatorname{int} = \frac{\pi i}{2} + k\pi i$$

$$\Rightarrow \operatorname{int} = \frac{2k+1}{4n}$$



Ex: $\left| \frac{1}{2} T_n \right| \rightarrow 0$ for $n \rightarrow \infty$

$$2^{n-1} \cdot \ln T_n$$

Now if $\frac{1}{T_n} = \frac{1}{2^{n-1}} \cdot T_n$ s/c

Since $\left\| \frac{1}{T_n} \right\| = \frac{1}{2^{n-1}}$, $n \rightarrow \infty$

$$\alpha_i = \cos\left(\frac{\pi i}{n}\right) \rightarrow \text{points}$$

Gegeben $x_j n \circ \alpha \cdot 0 \leq i \leq n$

points on Γ / T_n

and we have $\int_{T_n}^{\Gamma} f(x) dx = \int_{T_n}^{\Gamma} \sum_{j=0}^n \alpha_j e^{2\pi i j x} dx$

$$||f - \Pi_{\tilde{C}^{(n)}}(f)|| \leq \frac{|f^{(n+1)}(\xi)|}{(n+1)!} \cdot \|T_n\|_\infty =$$

$$\frac{|f^{(n+1)}(\xi)|}{(n+1)!} \cdot 2^{n-1}$$

—

$$(c_0, c_1, \dots) \rightarrow \text{S'0'0'IC 2230}$$

$$P_0, P_1, \dots \quad \deg(P_i) < i$$

δ_i

P_i

$$P_{i+1}(x) = P_i(x) + a_{i+1,0}(x-c_0) \dots (x-c_c)$$

$$a_{i+1} (c_{i+1} - c_0) \dots (c_{i+1} - c_i) = f_{i+1} - p_i f_{i+1}$$

$$\underline{a_{i+1}} = \underline{(c_{i+1} - c_0) \dots (c_{i+1} - c_i)} = \frac{f_{i+1} - p_i(f_{i+1})}{f_{i+1} - p_i(f_{i+1})}$$

$$\underline{[c_0, \dots, c_{i+1}]} f$$

$$\underline{[c_0, \dots, c_{i+1}]} f \subseteq \underline{[c_0, \dots, c_i]} f \sim \underline{[c_1, \dots, c_{i+1}]} f$$

$c_{i+1} - c_0$

$$\tilde{C} = (c_0, \dots, \overset{\text{:=} c_i}{c_{i+1}}, \dots, c_{i+1})$$

$$\underline{P_{\tilde{C}}(x)} = P_{\tilde{C}_{i+1}} - \frac{(x - c_0)}{(c_{i+1} - c_0)} (P_{\tilde{C}_{i+1}} - P_{\tilde{C}_0}) =: q(x)$$

$\text{if } 0 < j < i+1 \text{ do } : [n] 33$

$$q(c_j) = f_j = P_{\tilde{C}}(c_j)$$

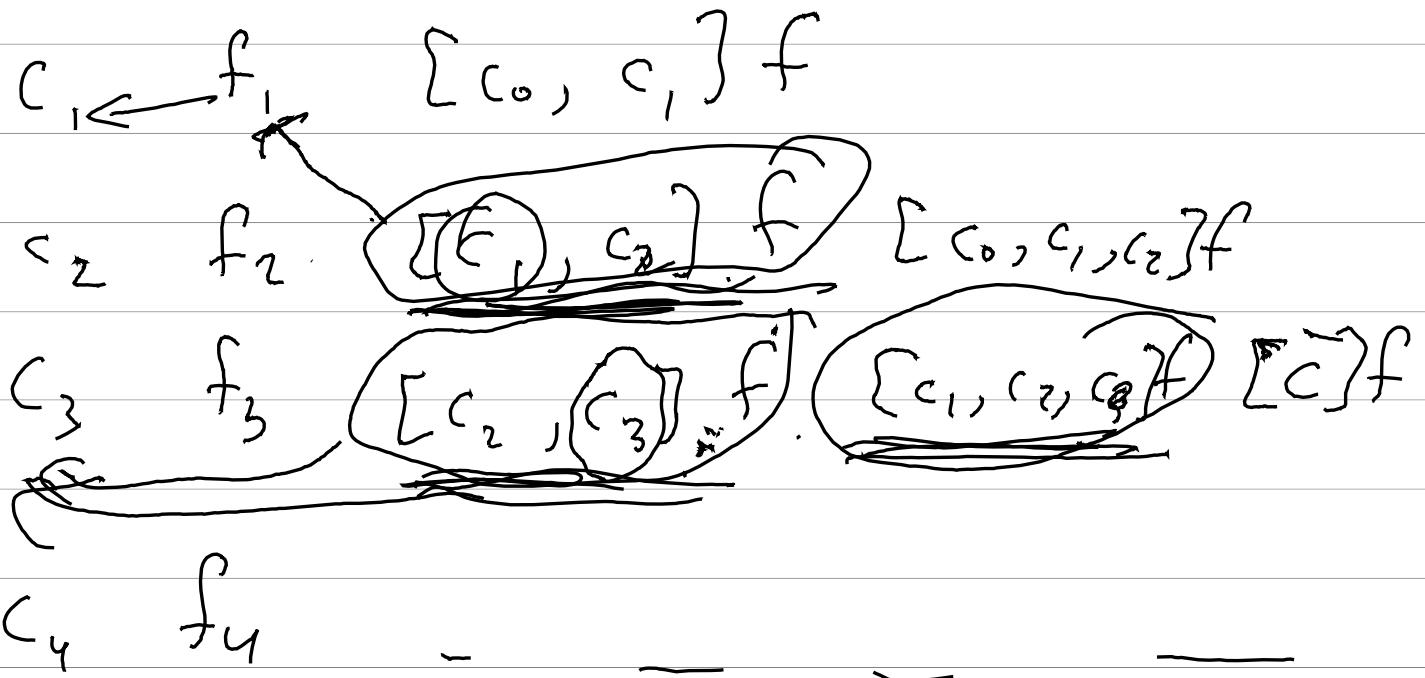
$$q(c_0) = P_{\tilde{C}_{i+1}}(c_0) = f_0 = P_{\tilde{C}}(c_0)$$

$$q(c_{i+1}) = P_{\tilde{C}_{i+1}}(c_{i+1}) - (P_{\tilde{C}_{i+1}}(c_{i+1})) -$$

$$P_{\tilde{C}_0}(c_{i+1}) = P_{\tilde{C}_0}(c_{i+1}) = f_{i+1} = P_C(f_{i+1})$$

c f

c_0 f_0



$$\{c_1, c_2, c_3\}f = \frac{\{c_2, c_3\}f - \{c_1, c_2\}f}{c_3 - c_1}$$

$$\bar{c} = c_0, \dots, c_i$$

$$P_{\bar{c}}(x) = P_{\bar{c}_{\leq i}}(x) + [\bar{c}] f \cdot \prod_{j < i} \pi(x - c_j)$$

$$\|P_{\bar{c}}(x) - P_{\bar{c}_{\leq i}}(x)\| = \|[\bar{c}] f \cdot \prod_{j < i} \pi(x - c_j)\|$$

$$\hookrightarrow \underbrace{\left[P_{\bar{c}}^{(i+1)}(\xi) \cdot \prod_{j < i} \pi(x - c_j) \right]}_{(i+1)}$$

$$\underline{\underline{f}} \left[\begin{array}{c} c_0, c_1, \dots, c_n \\ f_0, f_1, \dots, f_n \end{array} \right]$$

$$P_{\bar{C}}(x) = [\bar{c}] f(x^n) + \dots =$$

$$[\bar{c}] f(x - c_0) \dots (x - c_n) + P_{\bar{c}_{n+1}}$$

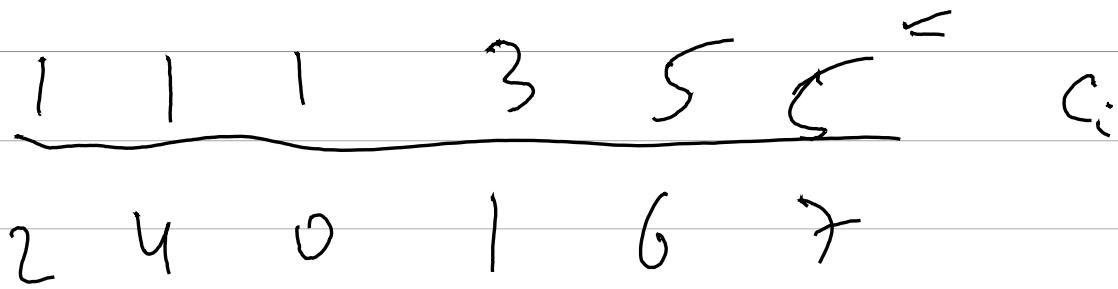
$$\hat{c}_i = \{c_0, \dots, c_n\} \setminus \{c_i\}$$

$$[\bar{c}] f = \frac{[\hat{c}_0] f - [\hat{c}_n] f}{c_n - c_0}$$

c_0, \dots, c_h

f_0, \dots, f_n

$$\bar{C} = 3 \cdot \{ \} + \{ \} + 2 \cdot \{ \}$$



$$P(1)=2, \quad P'(1)=4, \quad P''(1)=0$$

$$P(3)=1, \quad P(5)=6, \quad P'(5)=7$$

$$P_{\bar{C}}(x) = (\bar{C} \bar{f}) \cdot x^4 + \dots$$

$$\hat{c}_i = \bar{c} - \{c_i\}$$

$$\bar{C} = \sum n_i \{c_i\} \quad \deg(\bar{C}) = \sum n_i = n$$

$$\int_C c_i \neq c_j \text{ and } \underline{\text{is simple}}$$

$$\{\tilde{c}\} f = \frac{\sum \tilde{c}_i f - \sum \tilde{c}_j f}{c_j - c_i}$$

$$\tilde{c} = \sum_{k=1}^m a_k [c_k] \quad \underline{\text{closed}}$$

$$n = \deg(\tilde{c}) = \sum a_k$$

$$N(\tilde{c}) = n = \infty \quad \leftarrow \text{not possible}$$

$$n_k > 1 \quad \epsilon' \leq \epsilon \quad n-k > 0 \quad \text{and}$$

$$\tilde{d} = d_\varepsilon = \tilde{c} - \{c_n\} + \{c_n + \varepsilon\}$$

$$\int_C \tilde{d} = \int_C c_n + \varepsilon \quad \varepsilon > 0 \quad \text{and}$$

$$N(\tilde{d}) < N(\tilde{c})$$

$$[\tilde{d}]f = \frac{[\tilde{d}_i]f - [\tilde{d}_j]f}{\tilde{d}_j - \tilde{d}_i}$$

$$\text{Definim } \sum_{i=1}^n \tilde{d}_i f_i = \sum_{i=1}^n c_i f_i$$

$$\text{at } x_0 \text{ we have } \tilde{d}_i f_i = c_i$$

$$= \lim_{\varepsilon \rightarrow 0} \int_{x_0-\varepsilon}^{x_0+\varepsilon} f(x) dx$$

$$[(n-1)[c_0] + [c_0 + \varepsilon]]f \xrightarrow{\varepsilon \rightarrow 0} [n[c_0]]f$$

$$[c_0, c_0 + \varepsilon]f = \frac{f(c_0 + \varepsilon) - f(c_0)}{\varepsilon} \xrightarrow{\varepsilon \rightarrow 0} f'(c_0)$$

$$P_n(c_0) = \sum_{k=0}^n \frac{f^{(k)}}{k!} (x - c_0)^k$$

$$c_0 = c_1 = c_2$$

$$c_5 = c_6$$

$$c_0 \quad f_0$$

$$c_1 \quad f_0 = [f]_{c_0, c_1} f = f_1$$

$$c_2 \quad f_0 \cdot f_1 \quad f_2$$

$$c_3 \quad f_3 \quad [c_2, c_3] f = \frac{f_3 - f_0}{c_3 - c_0} \cdot [c_1, c_2, c_3] f = \frac{[c_2, c_3] f - f_1}{c_3 - c_0}$$

$$c_4 \quad f_4$$

$$c_5 \quad f_5$$

$$c_6 \quad f_5 \quad f_6$$

$$c_7 \quad f_0 \quad [c_6, c_7] f = \frac{f_0 - f_5}{c_7 - c_6}$$

c_6^{11}

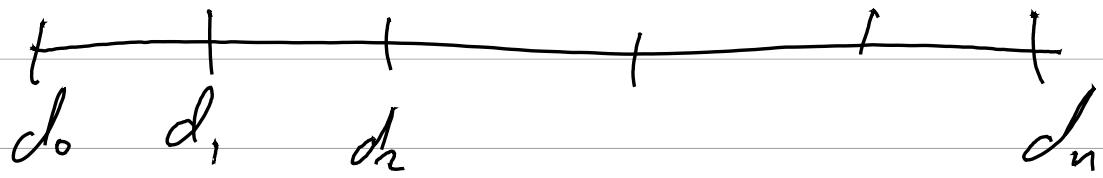
$$[c_5, c_3] f$$

$$\underbrace{p'j's \circ}_{a < b \in R}$$

$$1g/\delta n \quad \sim \gamma / p$$

$$a = d_0 < d_1 < \dots < d_n = b$$

↓

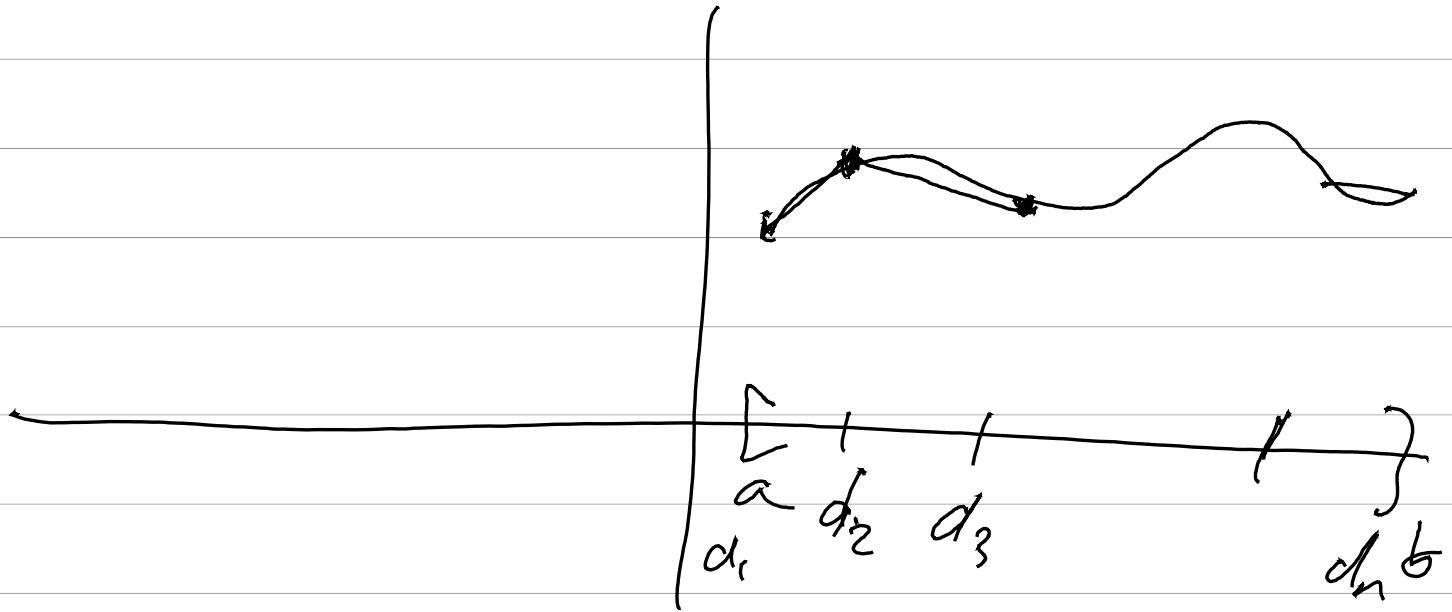


$$S_m^k(D) = \left\{ s \in C^k[a, b] \mid s|_{[d_i, d_i]} \right\}$$

$m \geq 1, 2, \dots, k$

$$k < m$$

$$S_1(\delta) = \int_{\sqrt{d}}^{\sqrt{d+\delta}} \sin(x)^{\frac{1}{\delta}} dx$$



数值积分
梯形法

梯形法
将区间等分，用中点值代替各子区间的平均值

$$|f(x) - S(x)| \leq \frac{M}{2} \cdot |(x-d_i)(x-d_{i+1})| \leq \frac{M}{8} \cdot [(d_{i+1} - d_i)]^2$$

$$M = \max_{x \in [d_i, d_{i+1}]} f''(x)$$

(a) \rightarrow λ) \wedge $\forall \lambda$ $\exists K$ $\exists c$ $\forall x$

$$\frac{M}{8} \cdot |\Delta|^2$$

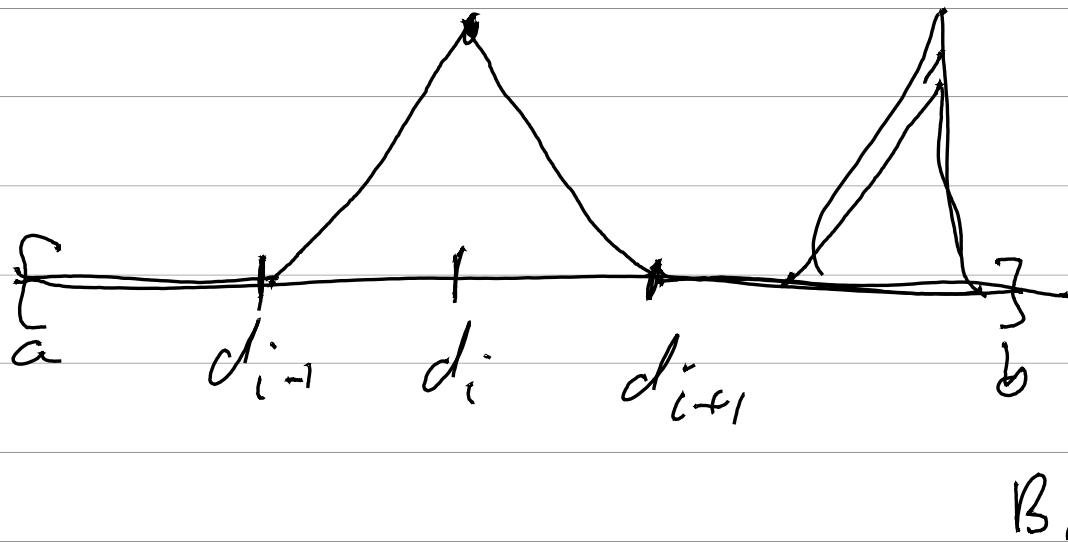
$|\Delta| = \text{max } \sqrt{\tau} \text{ for } \tau \in C$

$$\|f - \varsigma_1\| \leq \underbrace{\|f - \varsigma_1^0\|}_{\text{error}}$$

$V \rightarrow \text{def } \mathcal{W}, \wedge \text{ error} - \varsigma_1^0(\delta)$

126) 0.025 \rightarrow error

R^{Ed_1, \dots, d_n} μ



$$\langle B_i, B_j \rangle \neq 0$$

~~$|i-j| \leq 1$~~ $\forall i, j$

~~such that~~

$$\hat{s} = \sum c_i B_i$$

~~such that~~ $f \in \mathcal{F}_{\gamma_1}$

~~such that~~ $f \in \mathcal{F}_{\gamma_1}$

$$T \bar{c} = \bar{d}$$

$$T = \left(\langle B_i, B_j \rangle \right)_{i,j} \in \mathbb{R}^{C \times C}$$

$$d_i := \langle f, B_i \rangle$$

$$T = \begin{pmatrix} & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \end{pmatrix}$$

• $\sum_i d_i^2 / C$ "Trace"

$$\|f - \hat{g}\|_\infty \leq 4 \cdot \overbrace{d(f, S_1^\circ(\delta))}^{> 3\gamma/\delta}$$

$\therefore 3 \rightarrow \text{approx} \approx 1520$

دلتا '3' for f the 2121

نحوه . $S_3'(d)$ π

- $c \geq d \leq e^3$ for f

$s(d_i) = f(d_i)$ i for f

$s|_{[d_{i-1}, d_i]}$ \geq approx 1812

$s'(d_i) = m_i$

$m_i = \underline{\underline{f'(d_i)}} \cdot l_c$

- c m_i part of sum of 2

$s \in S_3^2(D)$

1) def and lin

. (def) f for $\boxed{f: \mathbb{R} \rightarrow \mathbb{R}}$

for map is f

. (def) or if $[a, b]$

numbers 113w in range

$f(x) = 0$ if else

then return if else return x

return $\left(\begin{array}{c} x \\ \vdots \\ x_n \end{array} \right)$

$F(t, x, x', \dots, x^{(n)}) = 0$.?

$x(1) = x_1$, $x(0) = x_0$

$f(a) \cdot f(b) \leq 0$ \checkmark C is so,

Now we can see $\exists c' \in]a, b[$ such that

$f(a) \cdot f(c') < 0$ i.e. $a' \in f^{-1}(0)$

$f(a) \cdot f(b) \leq 0$ \checkmark " $c = \frac{a+b}{2}$

$a' < c$, $f(a) \cdot f(c) \leq 0$ \checkmark

$\{a, c\} \cup \{c, b\}$ \Rightarrow $\exists c' \in f^{-1}(0)$

$\overbrace{\dots}^{\text{f}(x)}$

$f(c) \geq 0$
 $\underbrace{\leq 0}_{\text{f}(c)}$

$X_n - a \in \mathbb{Q}$ \checkmark $\exists c' \in f^{-1}(0)$
 $c \in \mathbb{R}$ \checkmark $\exists c' \in f^{-1}(0)$

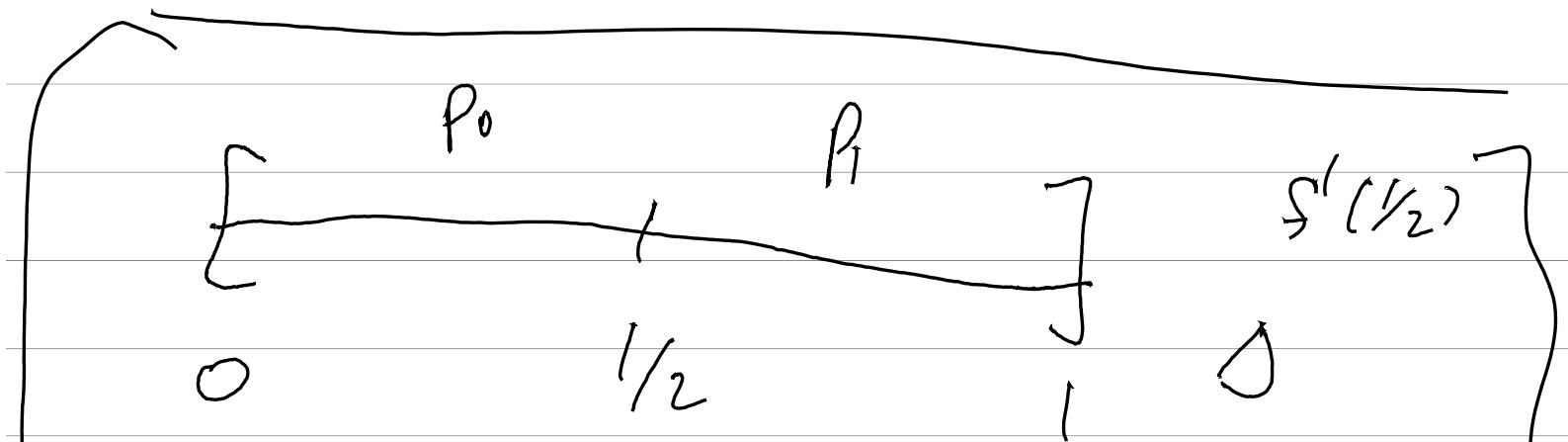
$$|x_n - a| \leq \frac{(b-a)}{2^n} = \varepsilon_n$$

→ $\rho \approx 2$

$$\frac{\varepsilon_{n+1}}{\varepsilon_n} \underset{n \rightarrow \infty}{\sim} \frac{1}{2}$$

\sqrt{c} $P > 30\%$ value

$$\cdot (P > 1 \text{ value}) \quad \overbrace{\varepsilon_{n+1} / \varepsilon_n}^{\rightarrow c > 0} \rightarrow c > 0$$



$$f \quad S \subset S_3'(\Delta) \quad P_0'(1/2) = P_1'(1/2)$$

$$P_0(0) = f(0), \quad P_0(1/2) = f(1/2), \quad P_1(1/2) = f(1/2), \quad P_1(1) = f(1)$$

$$\cdot f(x) = 0 \quad [a, b]$$

$$x_i \rightarrow 0 \quad f(c) = 0$$

$$\left| \frac{x_{i+1}}{x_i} \right| < \varepsilon_i \quad \frac{\varepsilon_{i+1}}{\varepsilon_i} \rightarrow c < 1$$

$$r^l, c, \delta \sim \mathcal{O}(1)$$

$$p>k$$

$$\frac{\varepsilon_{i+1}}{\varepsilon_i} \rightarrow c > 0$$

p چون کوچک

1' 3' 1' 2' 3' 0' : 1' 1'
 f_0, \dots, f_n 1' 3'

For $n \in \mathbb{N}$ define $\varphi_{\{a,b\}}$ by
 $\{a,b\} \subset \text{range } \varphi_{\{a,b\}}^n$

$f_{n+1} = -f_n$, $f_{-1} = 0$ /not

(1') f_n a ND range ref)

$r \in \{a,b\}$ So $0 \leq i \leq n$ /n

$f_{i+1}(r), f_{i-1}(r) \in S/r$ $f_i(r) = 0$ $\sim c$

or $\exists r \in \Gamma(x)$ $\begin{cases} \text{no } \\ \text{if } S \setminus \{r\} \end{cases}$

$f_0(x), \dots, f_n(x)$ 1' 3' 0' e range

1(a)-oth b. f_n is max in $\{x : x \in$

ר \in $\{a, b\}$ \Rightarrow $f(r) \in \underbrace{\{a, b\}}$

ר \in $[c, d]$ \Rightarrow $f(r) \in [a, b]$

$[a, b] \rightarrow$ ר \in $[c, d]$

ר \in $[c, d]$ \Rightarrow $f(r) \in [a, b]$

ר \in $[c, d]$ \Rightarrow $f(r) \in [a, b]$

$\left[\begin{array}{c} f \\ x \end{array} \right] \in \left[\begin{array}{c} x \\ x \end{array} \right] \in \left[\begin{array}{c} x \\ x \end{array} \right] \in \left[\begin{array}{c} x \\ x \end{array} \right]$

ר \in $[a, b]$ \Rightarrow $f(r) \in [a, b]$

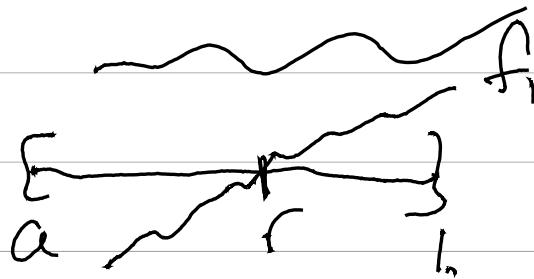
$r \in [a, b] \Rightarrow f(r) \in [f(a), f(b)]$

$n \in \mathbb{N}$ $\exists r \in \mathbb{R}^+$: $f_{n+1}(x) < f_n(x)$

$\checkmark n=0$

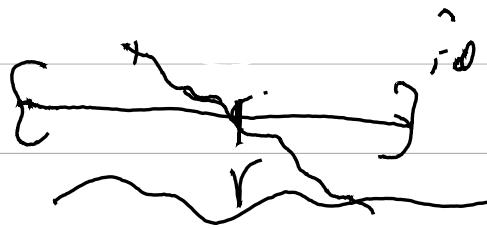
$\exists r \in \mathbb{R}^+$ $\forall x \in \mathbb{R} : f_0(x) < r$ $\underline{n=1}$

$\exists r \in \mathbb{R}^+$ $\forall x \in \mathbb{R} : f_1(x) < r$



$f_0(a) = 0$

$f_1(b) = r$



$$f_1(r) = 0 \Rightarrow f_0(r) \cdot f_1'(r) < 0$$

$$f_0' = -f_1'(r)$$

$$f_0'(r) < 0, f_1'(r) < 0$$

$\epsilon' \rightarrow n - 5$ ו L_0 מינימום f'

: מינימום f'

לפ x_1 x'_0 ל x_1 . $f_1(r) \neq 0$. A

רנ"ל יק"ר $f_1, \dots, \underline{f_{n+1}}$ ניגו,)

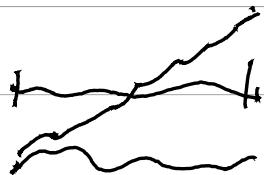
ר'ג'ג'ג' \cup , ר'ג'ג'ג' מ'ג

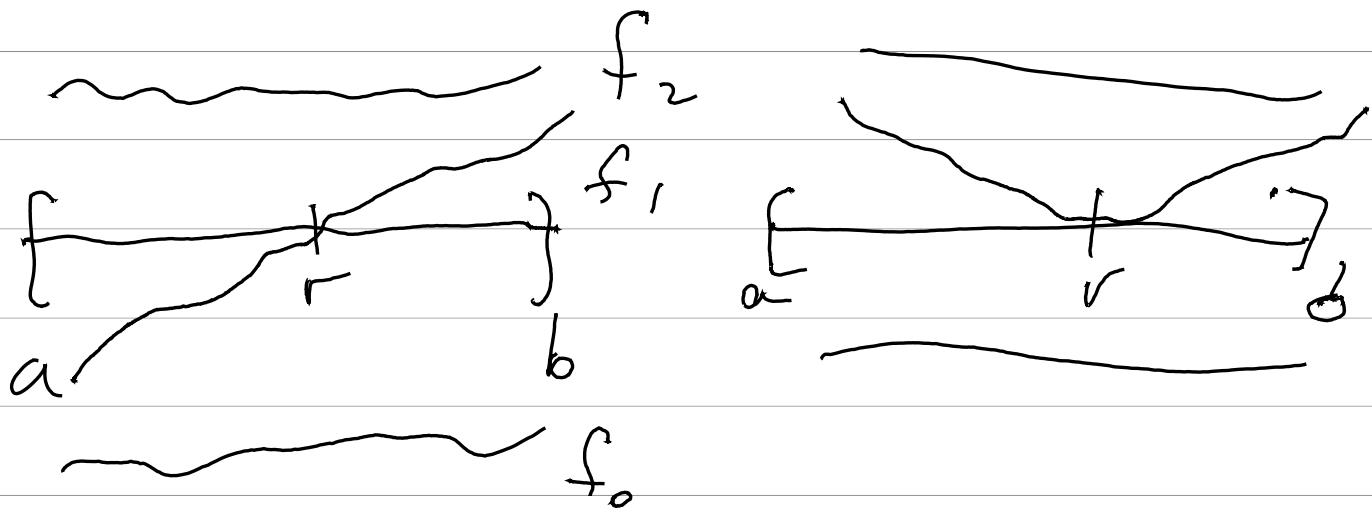
ר'ג'ג'ג' |I| 1-p f(1)

$f_0, f_1 \rightarrow$ C ר'ג'ג'ג' . $f_1(r) = 0$. 2

$f_0(r) \cdot f_1(r) < 0$ ר'ג'ג'ג' ס'

$f_2(r) \neq 0$ ס'ג





$\text{def } f_1 = P \quad \text{et} \quad \wedge' \cup J \cdot (\underline{\text{f}_1 / \text{c}_1 \text{ and } J})$

$\text{def } G/\text{e}_2 \quad \text{and } \text{e}_1/\text{e}_2 \quad \text{as}$

$$f_{n-1} = P^1, f_n = P \quad \gamma' \text{?} \text{J}$$

~~$$f_{k+1} = q_k \cdot f_k - f_{k-1}$$~~

$$n \leq k-1 \quad \gamma' \text{?} \text{J} \quad \deg(f_{kn}) < \deg(f_k) \quad \text{et} \quad \text{e}_1$$

$$\begin{aligned} & \text{def } f_1 = P^1, f_2 = P^2, \dots, f_n = P^n \\ & \text{def } f_{k+1} = q_k \cdot f_k - f_{k-1} \end{aligned}$$

רנינ גודל פולינום ב/c

בנין גודל פולינום ב/c
 $f_{n+1} \cdot f_{n-1} = -\underbrace{(f')^2}_{\geq 0} \leq 0$

המונומיאים $\{f_i\}$ נקראים מונומיאים של f .
 $\deg(f_i) = i$

המונומיאים $\{f_i\}$ נקראים מונומיאים של f .

$$f_{i+1} = (t-a_i) \cdot f_i - b_i f_{i-1}$$

$$\cdot b_i > 0 \rightarrow$$

$$\text{לפיכך } f_i(b) > 0, b > 0 \text{ ו } c \\ \sigma(b) \leq 0 \text{ ס'ו}$$

$\tau(a) \cap g(a) \subset \omega_1$

numeral i is f_i

ρ' / JC

τ_2' / c $\infty \delta \delta$ and $/ c$ $\rho \delta$

$\rightarrow f_{k+1} \in \omega_1$ $(3n)$

$\tau(a) \subseteq \omega_1$

$$x_{k+1} = \underbrace{x_k + x_{k+1}}_{\infty}, \in \omega_1$$

$\tau(x_{k+1}) \in \omega_1$

$\tau(x_{k+1}) \in \omega_1$

$\tau(x_{k+1}) \in \omega_1$

For $f(x) = 0$ if $\exists \gamma \in \text{sm}$

$\Rightarrow \exists \beta > \gamma$, f , $[a, b]$ $\forall f \geq 0$

$$f(a) \cdot f(b) < 0$$

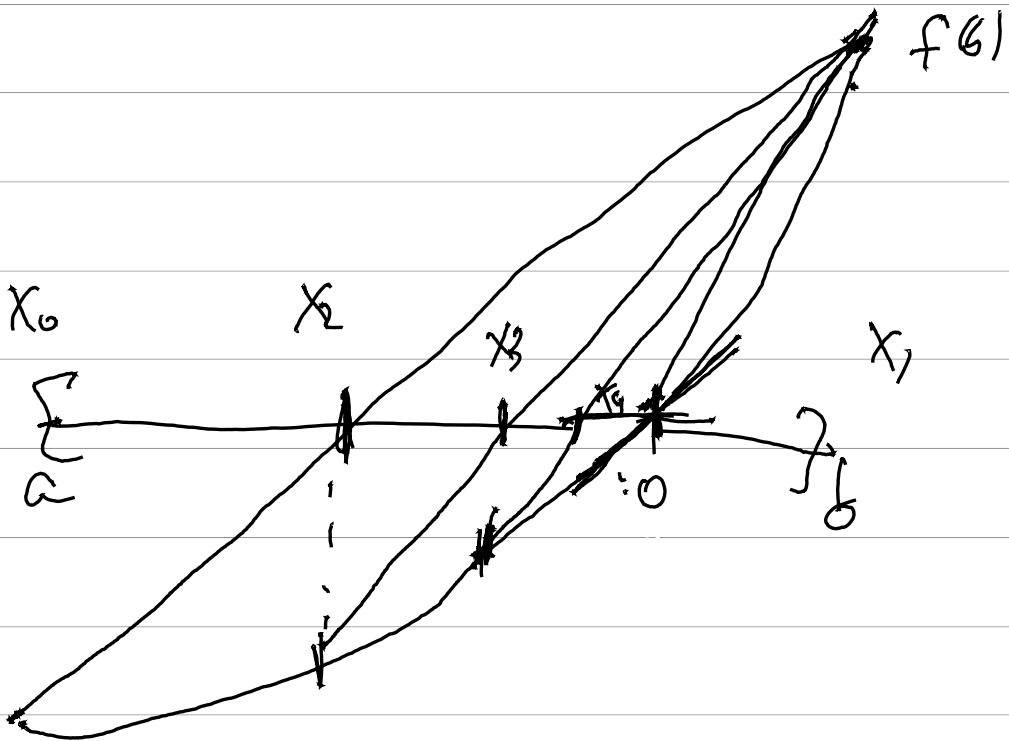


$$\frac{f(b)}{b-a}(x-a) + \frac{f(a)}{a-b}(x-b) = 0$$

\Downarrow

$$f(b)(x-a) - f(a)(x-b) = 0$$

$$x = \frac{f(b)a - f(a)b}{f(b) - f(a)}$$



$$x_{n+1} = \frac{f(x_n) \cdot x_{n-1} - f(x_{n-1}) \cdot x_n}{f(x_n) - f(x_{n-1})}$$

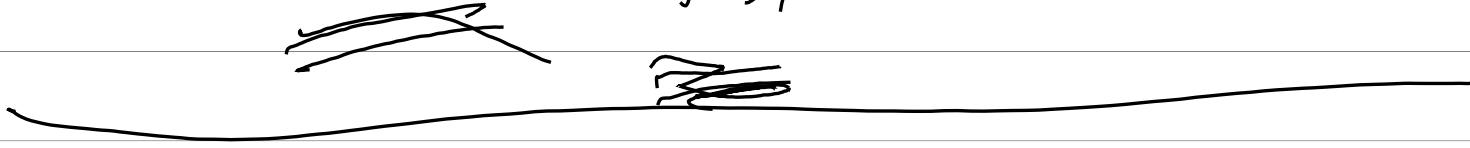
$$\frac{(f(x_n) - f(x_{n-1})) \cdot x_{n-1} + f(x_n) \cdot (x_n - x_{n-1})}{f(x_n) - f(x_{n-1})}$$

$$x_n' = f(x_n) \cdot \frac{x_n - x_{n-1}}{f(x_n) - f(x_{n-1})}$$

$$\frac{x_{n+1}}{x_n} = 1 - \frac{f(x_n)}{x_n} \cdot \frac{x_n - x_{n-1}}{f(x_n) - f(x_{n-1})} =$$

$$1 - \frac{f(x_n)}{x_n} \cdot \frac{x_n - b}{f(x_n) - f(b)} \rightarrow :$$

$$1 - f'(0) \cdot \frac{b}{f(b)} =: c$$



? \leftarrow , $n+1 \leftarrow ? \rightarrow f(\text{?})$

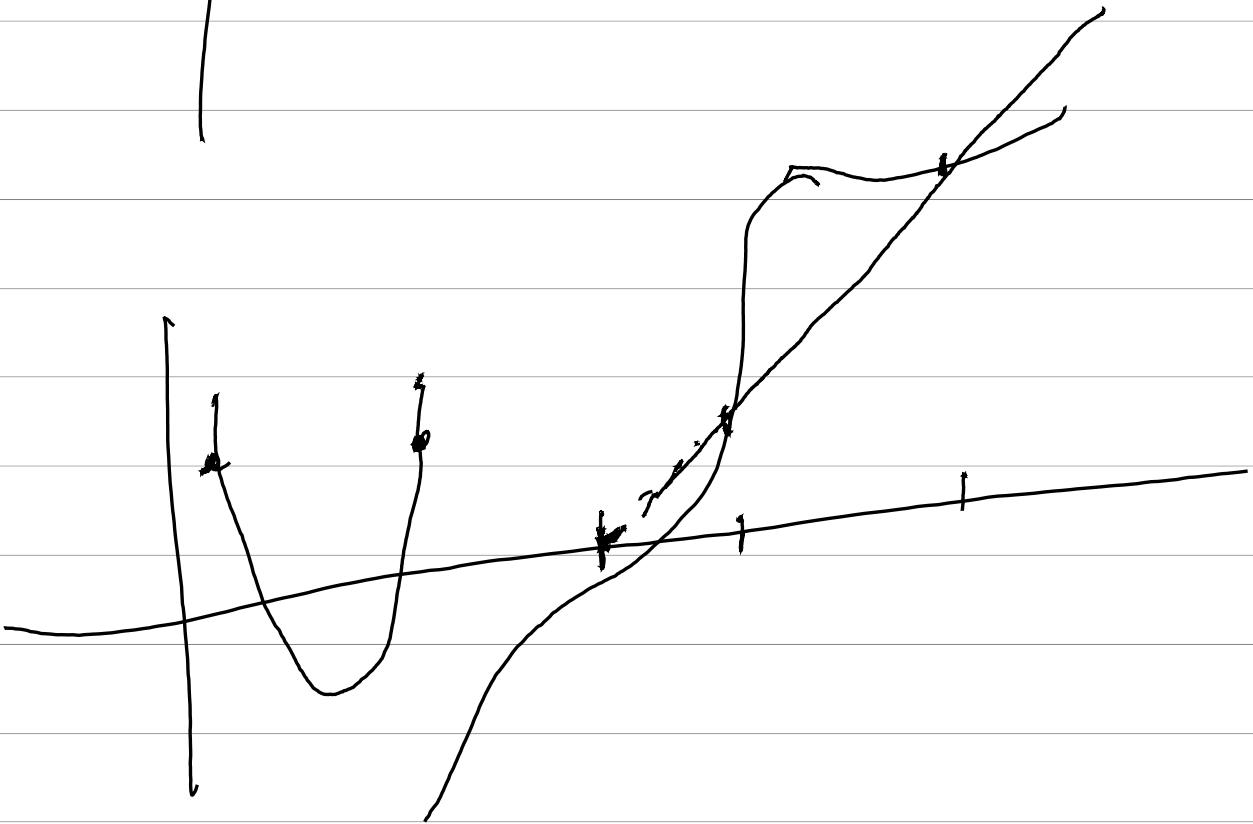
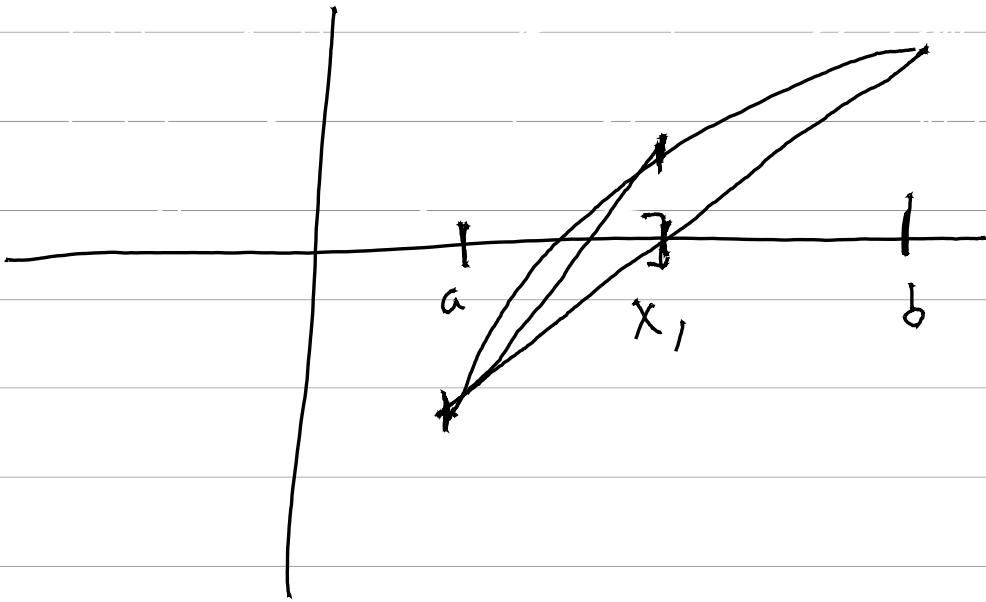
$$d = \frac{f(x_n) \cdot x_{n-1} - f(x_{n-1}) \cdot x_n}{f(x_n) - f(x_{n-1})}$$

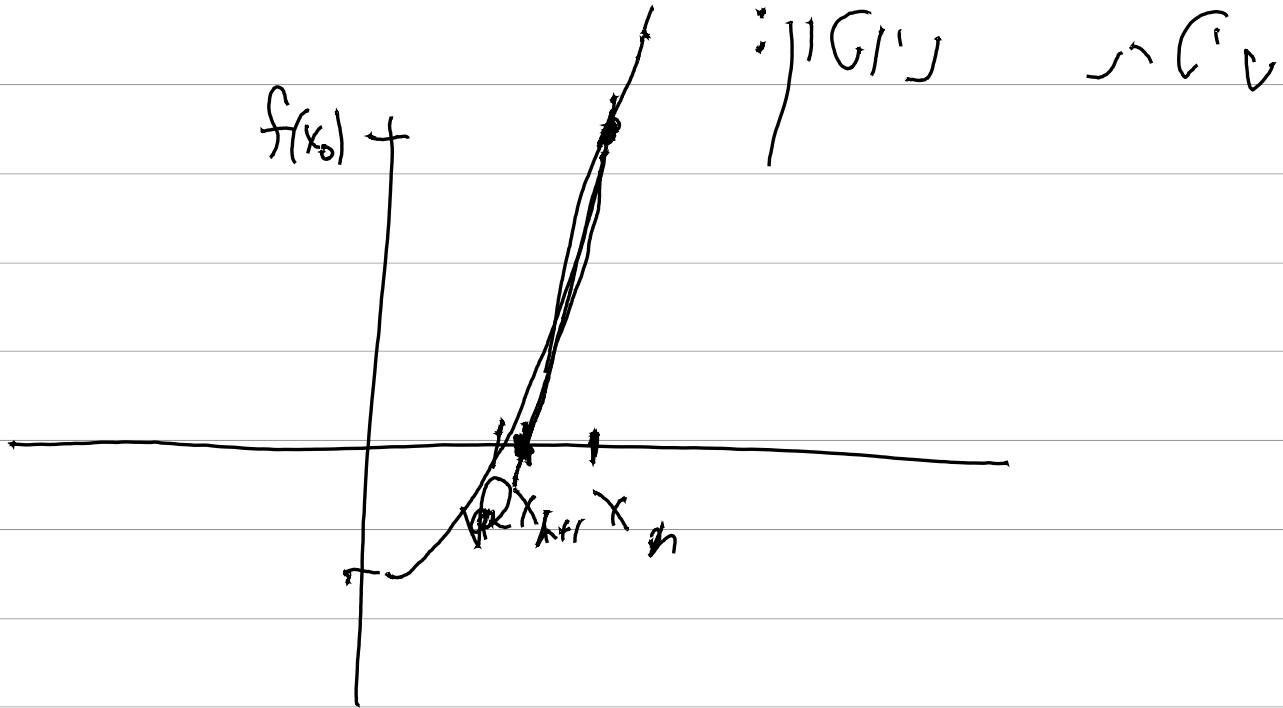
$$x_{n+1} = d \quad \text{if } f(d) \cdot f(x_n) \leq 0 \rightarrow /c$$

$$x_{n+1} = x_n, \quad x_n = d \quad \text{if } f(d) \cdot f(x_n) > 0 \rightarrow /c$$

Secant -> $\cup C_1$.1

$| \cup C_1' \cup C_1$.2





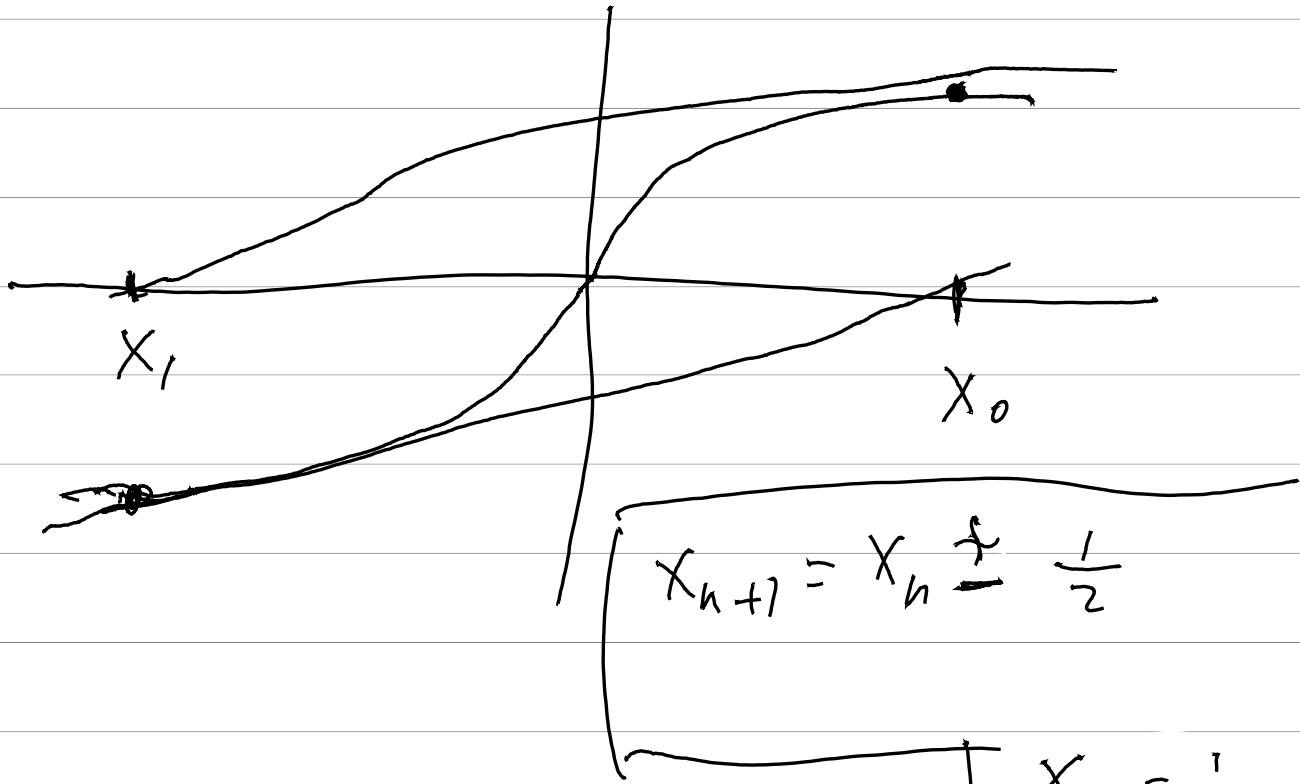
$$\left[\frac{x_{n+1} - x_n}{0 - f(x_n)} = \frac{1}{f'(x_n)} \right] \Rightarrow$$

$$x_{n+1} = x_n \circ \underbrace{\begin{pmatrix} f(x_n) \\ f'(x_n) \end{pmatrix}}_{\text{f(x_n)}}$$

\sqrt{a} src $\overbrace{c \wedge f^{-1} \circ}$ lceil d / 3

$$x^2 - a = 0 \quad (\Rightarrow a > 0)$$

$$x_{n+1} = x_n - \frac{x_n^2 - a}{2x_n} = \frac{1}{2} \left(x_n + \frac{a}{x_n} \right)$$



$$f(x) = \begin{cases} \sqrt{x} & x \geq 0 \\ -\sqrt{-x} & x \leq 0 \end{cases}$$

$$x_0 = \frac{1}{4}$$

$$x_1 = -\frac{1}{4}$$

$$x_2 = \frac{1}{16} = \infty$$

$$f'(x) = \begin{cases} \frac{1}{2\sqrt{x}} & x \geq 0 \\ -\frac{1}{2\sqrt{-x}} & x \leq 0 \end{cases}$$

$$\varphi(x) = x - \frac{f(x)}{f'(x)}$$

$$x_{n+1} = \varphi(x_n)$$

Se f ist
auf \mathbb{R} stetig und
durchl.

$$\varphi(x) = x - \frac{f(x)}{f'(x)}$$

in \mathbb{R} mit
einem
Grenz

$$\text{in } M \text{ mit } (M, d) \text{ mit}$$

$\varphi: M \rightarrow M$ ist
stetig

$$d(\varphi(x), \varphi(y)) \leq c \cdot d(x, y)$$

$c > 0$ mit $x, y \in M$

$X_{n+1} = \varphi(X_n)$, $\forall n \geq 0$, $\exists \lim_{n \rightarrow \infty}$

$\Rightarrow \text{Lip } X_0$

, $i \leq j$ $\Rightarrow \int_{x_i}^{x_j} \dot{x}(t) dt$

$d(x_i, x_j) \leq c^i \cdot \underbrace{d(x_0, x_{j-i})}_{\dots}$

$d(x_0, x_k) \leq d(x_0, x_1) + \dots + d(x_{k-1}, x_k) \leq$

$d(x_0, x_k) / (1 + c + c^2 + \dots + c^{k-1}) = \frac{1-c}{1-c} d(x_0, x_k)$

$\Rightarrow d(x_i, x_j) \leq \frac{c^i}{1-c} d(x_0, x_j) \rightarrow 0$

$c' \subset [c] \cap \cup_{i=0}^{\infty} (X_i)_{i \geq 0} \subset$

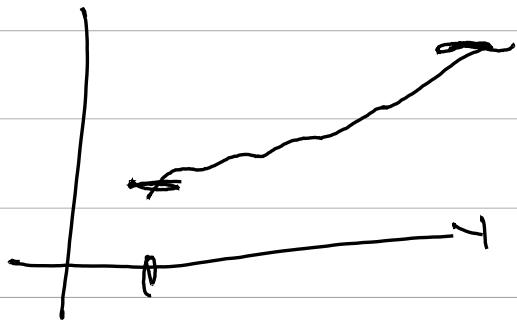
$(r^2, r^3, r^4) \subset \Delta \subset \cup_{i=0}^{\infty} (X_i)_{i \geq 0}$

$\varphi(\alpha) = \varphi(\lim_{i \rightarrow \infty} x_i) = \lim_{i \rightarrow \infty} \varphi(x_i) = \lim_{i \rightarrow \infty} x_i = \alpha$

$\text{Def}(\nu)$
 $\nu \in \mathbb{N}^{\mathbb{N}}$ $M \subseteq \mathbb{R}$ $\nu \in \mathbb{N}^{\mathbb{N}}$

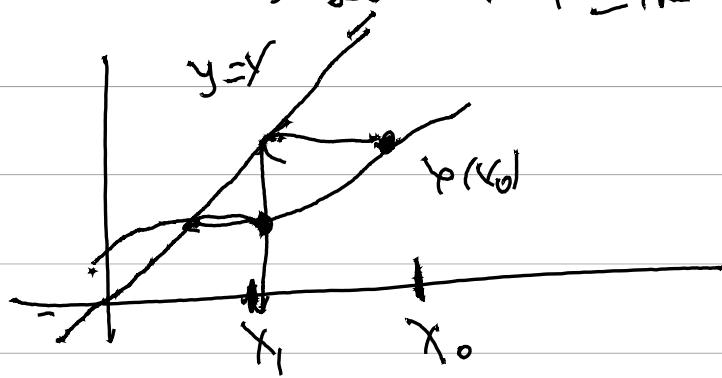
-1, No 3 to 7's & x

all N & f(c) $x \in M$ $\exists \delta \forall \epsilon < 1$



f is continuous \Rightarrow $\forall \epsilon \exists \delta$ $\forall x \in M$

$\varphi: M \rightarrow \mathbb{R}$
 $\varphi \in \mathbb{R}^M$ $M \subseteq \mathbb{R}^n$ $\varphi(x_0)$



$x^p - \alpha^p$ $\neq 0$ $\forall \alpha \in C$

$$\varphi'(\alpha) = \varphi''(\alpha) = \dots = \varphi^{(p-1)}(\alpha) = 0 \quad -1$$

($\varphi \in C^p(M)$) . $\varphi^{(p)}(\alpha) \neq 0$ -1

: p 1. α $\neq 0$ $\forall \alpha \in C$

$$\frac{x_{n+1} - \alpha}{(x_n - \alpha)^p} \rightarrow \frac{\varphi^{(p)}(\alpha)}{p!}$$

$$\varphi(x) = \alpha + \varphi'(\alpha)(x - \alpha) + \frac{\varphi^{(p-1)}(\alpha)}{(p-1)!}(x - \alpha)^{p-1} + \frac{\varphi^{(p)}(\alpha)}{p!}(x - \alpha)^p$$

$$\alpha + \frac{\varphi^{(p)}(u)}{p!}(x - \alpha)^p \Rightarrow u \in \{\alpha, x\}$$

$$x_{n+1} - \alpha = \frac{\varphi^{(p)}(u)}{p!} \cdot (x - \alpha)^p$$

לעסן גראונד

$$\varphi(x) = x - \frac{f(x)}{f'(x)}$$

$$\varphi'(x) = 1 - \frac{f'^2 - f \cdot f''}{f'^2} = \frac{f \cdot f''}{|f'|^2}$$

$$\varphi'(x) = 0$$

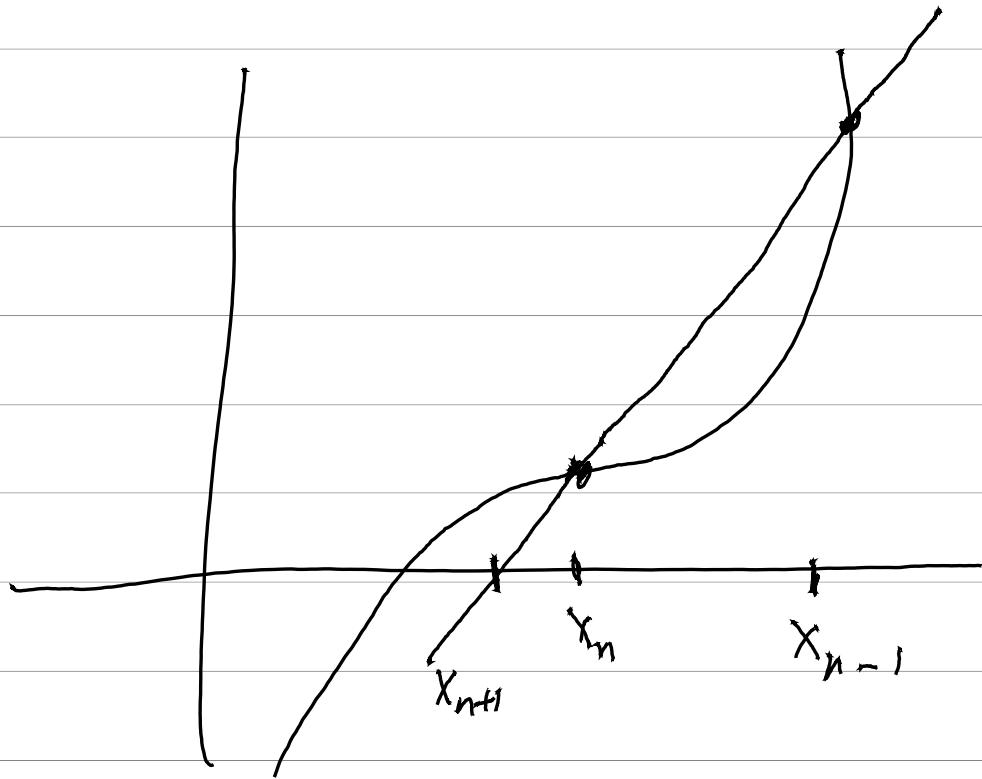
נתקה (ונרמזו) גראונד

ב' גראונד

$$u \text{ sod } \varphi'(u) \leq 0 \Leftrightarrow f'(u) \neq 0$$

ולא נרמזו גראונד

Secant \rightarrow C_V



$$\frac{x_{n+1} - x_n}{-f(x_n)} = \frac{x_n - x_{n-1}}{f(x_n) - f(x_{n-1})}$$

$$x_{n+1} = x_n - \frac{x_n - x_{n-1}}{f(x_n) - f(x_{n-1})} \cdot f(x_n)$$

α (red) en ℓ' e $\wedge \vee$

$$x_{n+1} - \alpha = x_n - \alpha + \frac{x_n - x_{n-1}}{f(x_n) - f(x_{n-1})} f(x_n) =$$

$$(x_n - \alpha) \left(1 - \frac{f(x_n)}{(x_n - \alpha)[x_n, x_{n-1}] f} \right) =$$

$$(x_n - \alpha) \left(1 - \frac{[x_n, \alpha] f}{(x_n, x_{n-1}) f} \right) =$$

$$(x_n - \alpha) \left(\frac{[x_n, x_{n-1}] f - [x_n, \alpha] f}{[x_n, x_{n-1}] f} \right) =$$

$$(x_n - \alpha)(x_{n-1} - \alpha) \cdot \left(\frac{[x_n, x_{n-1}, \alpha] f}{[x_n, x_{n-1}] f} \right)$$

$$(x_n - \alpha)(x_{n-1} - \alpha) \cdot M$$

$$m = \max_{t, s_Q} \left| \frac{f''(s)}{2f'(t)} \right| \rightarrow R_f, \rightarrow$$

∴ $f'(x_0)$

290 | { } 290 ↗

$$U_\alpha = \{x \mid |x - a| < \varepsilon\}$$

$$\text{If } \varepsilon \cdot m \leq 1 - \delta \quad \text{and} \quad x_{n-1}, x_n \in U$$

$\overbrace{\hspace{10em}}$

$$|x_{n+1} - x| \leq \varepsilon^2 m \leq \varepsilon \cdot 1 = \varepsilon$$

$$\therefore x_n \rightarrow d \quad \Rightarrow \exists' \delta \quad \forall n \exists N$$

$$|X_{n+1} - \alpha| \leq |X_n - \alpha| \cdot |X_{n-1} - \alpha| \cdot M \leq$$

$$\varepsilon \cdot |X_{n-1} - \alpha| \leq \varepsilon^2 (|X_n - \alpha|)^2$$

$$\underbrace{(\varepsilon \cdot M)}_1^n \cdot |X_1 - \alpha|$$

$$E_n = \underbrace{|X_n - \alpha|}_1 \cdot M$$

$$\frac{|X_{n+1} - \alpha|}{(|X_n - \alpha|)^P} = \frac{E_{n+1}/M}{E_n^P/M} \leq \phi$$

$$E_{n+1} \leq E_n \cdot E_{n-1}$$

$$\underbrace{P^2 = P + 1}_{\text{II}}$$

$$P = \frac{1 + \sqrt{5}}{2}$$

$$E_n \leq E^{P^n}$$

$$E = \max(E_0, E^{\frac{1}{P}})$$

$$E_{n+1} \leq E_n \cdot E_{n-1} \leq E^P \cdot E^{P^{n-1}} = E^{P^{n-1}(P+1)} = E^{P^{n+1}}$$

$$[x_0, x_1]f \doteq f'(u)$$

$$u \in \{x_0, x_1\}$$

$$[x_0, \dots, x_k] = \frac{f^{(k)}(u)}{k!}$$

$$u \in [a, b]$$

$$\therefore r^{\prime} N \cup S \rightarrow \int f'(r) dr$$

$$x_{n+1} = x_n - \underbrace{\frac{f(x_n)}{f'(x_n)}}$$

$$x^n + a \begin{cases} b_n = c_n = 1 \\ b_k = t b_{k+1} + c_k \\ c_k = t c_{k+1} + b_k \end{cases}$$

$$(x-t)(x^{n-1} + b_{n-1}x^{n-2} + \dots + b_1) + b_0 = P(x)$$

$$b_n = 1 \quad b_k = t b_{k+1} + c_k$$

3) 2. C.J.'s

$$f'(c_0)$$

$$c_0, \dots, c_n \quad f \rightsquigarrow P_{\bar{c}, f}$$

$$\underline{P_{\bar{c}, f}(x)} = [\bar{c}] f \cdot \underline{(x - c_0) \cdots (x - c_{n-1})} \dots$$

$$P^1(c_0) = [\bar{c}] f \cdot (c_0 - c_1) \cdots (c_0 - c_{n-1}) +$$

$$[c_0, \dots, c_{n-1}] f \cdot (c_0 - c_1) \cdots (c_0 - c_{n-1}) + \dots$$

$$f(x) = P_{\bar{c}, f}(x) + \underbrace{\frac{f^{(n+1)}(\xi(x))}{(n+1)!} \cdot (x - c_0) \cdots (x - c_n)}$$

$$f'(c_0) = P_{\bar{c}, f}(c_0) + \underbrace{\frac{f^{(n+1)}(\xi(c_0))}{(n+1)!} (c_0 - c_1) \cdots (c_0 - c_n)}$$

$$\text{�}\mathcal{F}_1, \quad h = \max\{|c_0 - c_i|\} \quad \forall c$$

$$h^u \rightarrow \underbrace{\text{near zero}}$$

$$c_1 = c_0 + h, \quad c_0 \quad \text{and} \quad \underbrace{\dots}$$

$$f'(c_0) = \frac{f(c_0+h) - f(c_0)}{h} + h \cdot \frac{f''(\cdot)}{2}$$

$$P_{\bar{c}, f}(x) = f(c_0) + \underbrace{(f(c_0) - f(c_1))}_{(c_0 - c_1)} \cdot (x - c_0)$$

$$f(c_1) - f(c_0)$$

$$h = c_1 - c_0$$

$$c_{-1} = c_0 - h, \quad c_1 = c_0 + h \quad -2$$

$$P_{\bar{C}, f}(x) = f(c_0) + [c_0, c_1]f \cdot (x - c_0) +$$

$$\underbrace{[c_0, c_1, c_{-1}]f}_{(x - c_0)(x - c_1)}$$

$$[c_0, c_1]f = \frac{f(c_1) - f(c_0)}{h}$$

$$[c_0, c_1, c_{-1}]f = \underbrace{[c_0, c_1]f - [c_0, c_{-1}]f}_{2h} =$$

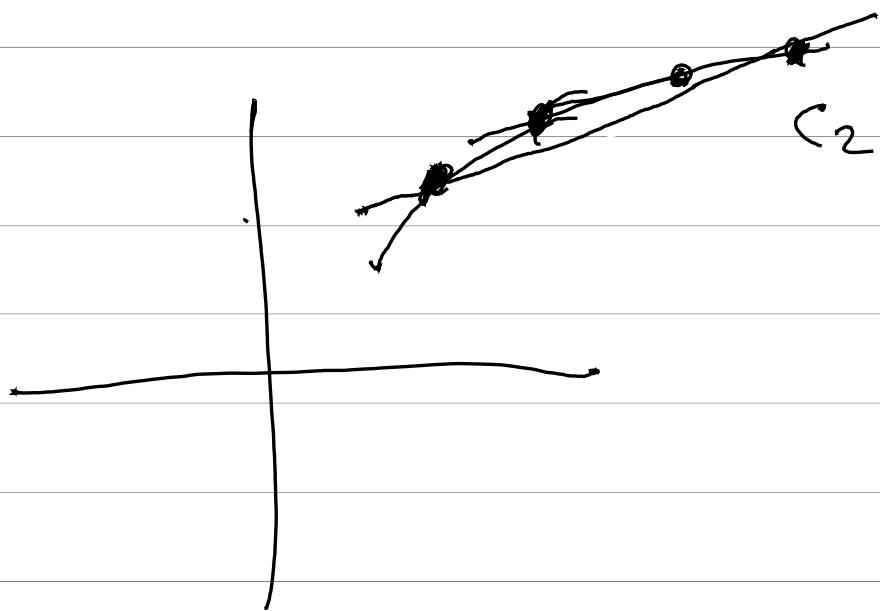
$$f(c_1) - f(c_0) + [f(c_{-1}) - f(c_0)]$$

$$\underbrace{- \frac{f(c_1) - 2f(c_0) + f(c_{-1})}{2h^2}}_{=} =$$

$$\left| \frac{f(c_1) - f(c_0)}{h} - \frac{f(c_0) - 2f(c_0) + f(c_{-1})}{2h} \right| =$$

$$\boxed{f(c_1) - f(c_{n+1})}$$

2 h



$$e \approx \frac{f'''(\xi)}{6} \cdot h^2$$

$$f_1 = f(c_1) + \varepsilon \quad : \text{plus a small error}$$

$$f_{-1} = f(c_{-1}) + \varepsilon$$

$$f'(c_0) = \frac{f(c_1) - f(c_{-1})}{2h} + \ell_2 =$$

$$\frac{f_1 - f_{-1}}{2h} - \left(\frac{\varepsilon}{h} \right) + \ell_2 =$$

in regression analysis

$$E(h) = \boxed{M \cdot h^2} - \underbrace{\frac{\varepsilon}{h}}$$

$$h_0 \Rightarrow \left(\frac{\varepsilon}{2M} \right)^{1/3} \quad E(h_0) = \frac{3}{2} (2M)^{1/3} \cdot \varepsilon^{2/3}$$

Up now) if $\int \sqrt{f(x)^2} dx$ f no E

$$f'(x_0) = \frac{1}{2\pi i} \oint \frac{f(x)}{(x-x_0)^2} dx$$



$$\underbrace{\approx 3 \gamma \langle C_j \rangle}_k$$

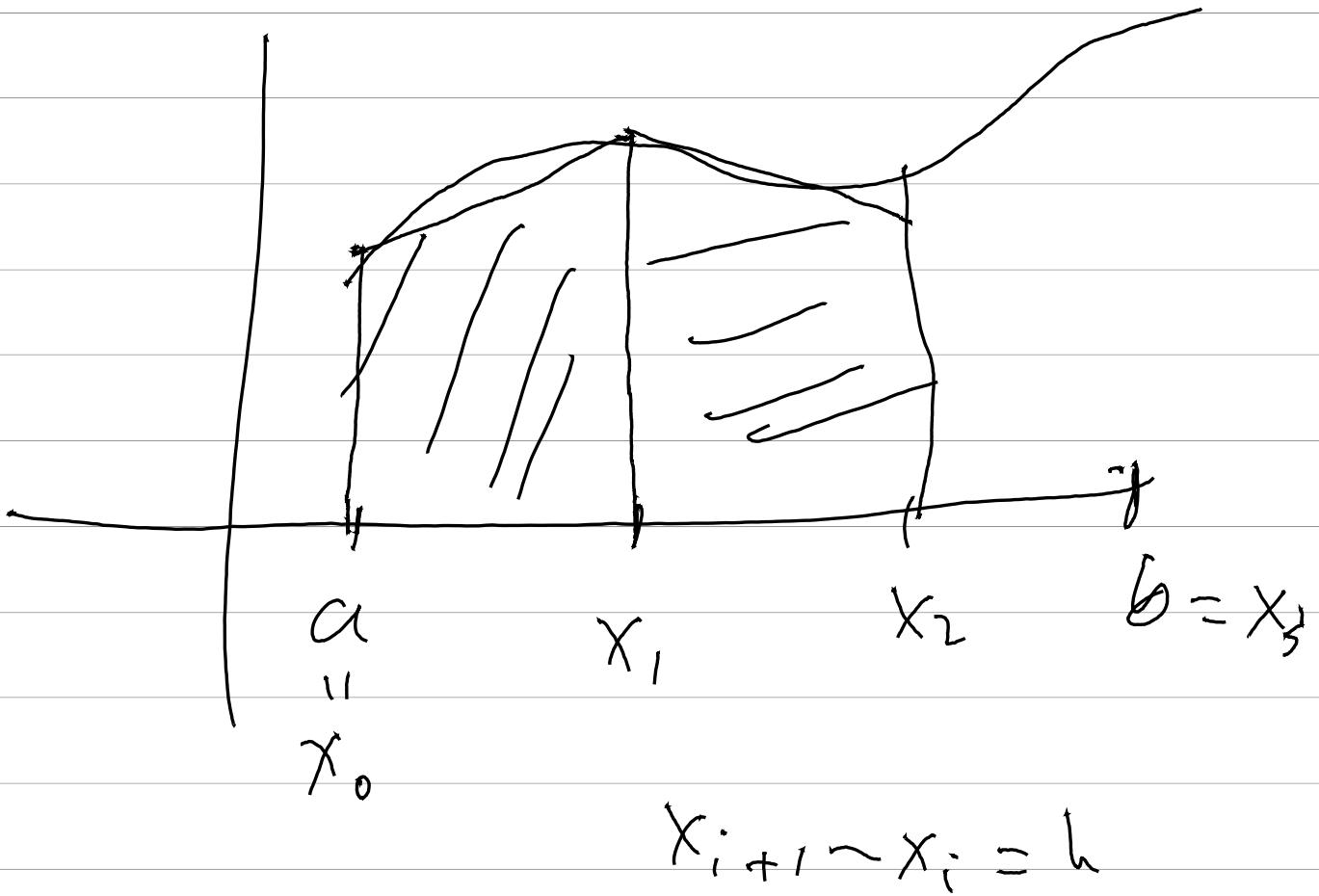
so it pers $\approx 3 \gamma$

$$\int_a^b f$$

$\rho^* \nu(f[a, b])$ so $\approx \int_a^b f$

$$a = x_0 < x_1 < \dots < x_n = b$$

$\approx \int_a^b$



$$\int_{x_i}^{x_{i+1}} f \approx \frac{f(x_{i+1}) + f(x_i)}{2} \cdot (x_{i+1} - x_i)$$

$$R_n(x) = \frac{f''(c)}{2} (x - x_i)(x - x_{i+1})$$

$$\int_{x_i}^{x_{i+1}} R_i(x) = \int_{x_i}^{x_{i+1}} (x - x_i)(x - x_{i+1}) dx.$$

$$\underbrace{\frac{f''(c_i)}{2}}_{2} = \frac{h^3}{12} \cdot f''(c_i)$$

$$\int_a^b f dx = h \cdot \left(\frac{1}{2} \cdot f_0 + f_1 + \dots + \frac{1}{2} f_n \right) +$$

$$\underbrace{-\frac{h^3}{12} \cdot \sum f''(c_i)}_{II}$$

$$E_h^T(f) = -\frac{h^2}{12} \cdot \underbrace{(b-a)}_n \sum f''(c_i) = -\frac{h^2}{12} (b-a) \cdot \frac{1}{n}$$

Numerical Integration

Simpson's rule for f
'y12' <math>\approx \frac{h}{3} (f_k + 4f_{k+1} + f_{k+2}) ->

x_{i+2}

$$\int_{x_i}^{x_{i+2}} f(x) dx = \frac{h}{3} (f_k + 4f_{k+1} + f_{k+2}) -$$

$$\overline{\int_a^b} h^S f^{(n)} (c_i)$$

$$\overline{\int_a^b} f = \frac{h}{3} (f_0 + 4f_1 + 2f_2 + \dots + f_n) +$$
$$E_n^S(f)$$

$$E_n^S(f) = -\frac{1}{180} \cdot (b-a) h^4 \cdot f^{(4)}(c)$$

$$[a, b] = [0, 2\pi]$$

$$E_n^T \cdot (e^{2\pi i kx}) = \int_0^{2\pi} e^{i kx} dx$$



$$\left(\frac{1}{2} e_k(0) + \sum_{i=1}^{n-1} e_k\left(\frac{2\pi i}{n}\right) + \frac{1}{2} e_k(2\pi) \right) \cdot \frac{2\pi}{n}$$

$$= 0 \quad k < n$$

結論 $\rightarrow f \in C$

$$f(x) = \sum_i a_i \cos(i x) + b_i \sin(i x)$$

$$E_F(f) = \sum_i a_i$$

$f \in C^r(\mathbb{R})$

$\forall c: \exists \beta / \gamma$

$$\underbrace{\int_{\text{mod } 0} f(x) dx}_{\text{def}} \geq a_i(f) \quad \forall c$$

$i^{-r} \quad \text{ind}$



$\gamma \approx 1.732$, $\sqrt{5} \approx 2.236$

$\int_0^x f(t) dt \approx \frac{1}{2} \gamma x^2$

$\lambda \approx 1.32$

b

$$\int_a^b f(t) \underline{w(t)} dt = \sum_{k=1}^n w_k \cdot f(\underline{t_k}) + E_n(f)$$

$A =$

$$\begin{matrix} 1 & 2 & 3 \\ \downarrow & \downarrow & \downarrow \\ X & S \end{matrix}$$

A_1, A_{-1}

?

$$T: A \rightarrow A \quad T(f) = f \circ c \quad A,$$

$\underbrace{\mu}_{=1}$

$$T^2 = Id$$

$$\overbrace{T^2 = Id}$$

$$T \text{ 使得 } T \circ f = f$$

$$A_i = \text{span}_i \text{ 为 }$$

$$\begin{cases} T^m = Id \\ T^G = 0 \end{cases}$$

$$x + \frac{1}{x}$$

$$T(x) = \frac{1}{x}$$

$$A^m = \left\{ t \in \mathbb{C}[x, \frac{1}{x}] \mid t(x) = \sum_{i=-m}^m a_i x^i \right\}$$

$$\dim A^m = 2m+1$$

$$\underbrace{(x - \frac{1}{x})^k}_{\in A^m} \in A_1 = A^m \cap A, \quad \begin{matrix} 0 \leq k \leq m \\ (x - \frac{1}{x}) \cdot (x - \frac{1}{x})^k \end{matrix}$$

רְאֵבָנָן רְנוּן 'ז' סֶקְטָרִי 'ק

$$\int_a^b \underline{f(t)} \underline{w(t)} dt = \sum_{i=1}^n (\underline{w_i} f(t_i)) + E_n(f)$$

, ר' ג'ס 'ק) "פְּגַם" - w(t)

$$\int_a^b f(t) w(t) dt, \text{ ג'ס}$$

(f ~) \int_s

ר' ג'ס (ה'גנ'ס) כ'ג'ס

: ר' ג'ס 'ג'ס . t_i \rightarrow \int_s

m \geq n \text{ ו } \int_s E_n(f) = 0

. ר' ג'ס m \rightarrow \rho y

$$1, \text{px} \sqrt{\lambda / 3} p^{1/2} \leq n - V$$

$$\psi(f) = \int_{\mathbb{R}} f(t) w(t) dt$$

WJS 28.07.2017

$\psi: V \rightarrow \mathbb{R}$

$$S_t(f) = (f(t_1), \dots, f(t_n))$$

$$S_T: V \rightarrow \mathbb{R}^n$$

$$\psi: \mathbb{R}^n \rightarrow \mathbb{R}$$

$$P_k \quad \left. \begin{array}{l} \dim P_k = k \\ \end{array} \right\}$$

P_k $k > n$ \Rightarrow $\dim P_k = n < k$ \Rightarrow

$$\psi|_{P_k} = \underbrace{\psi \circ S_T}_{\sim} |_{P_k} \quad * \quad P_k \subseteq V$$

13.3.

$$S_{\tilde{t}}|_{P_n} : P_n \rightarrow \underline{\mathbb{R}^n}$$

(3) \exists $\delta > 0$ $\forall \epsilon > 0$

$$\varphi = \psi \circ S_{\tilde{t}}^{-1} \quad \text{by } \text{SC}$$

. ($\exists \delta' \forall \epsilon < \delta'$) $\exists r > 0$ $\forall x \in U_r$

- $\exists \delta' \forall \tilde{t}$ $|t - \tilde{t}| < \delta' \Rightarrow$

$$\psi|_{P_{n+1}} = \varphi \circ S_{\tilde{t}}$$

$$\psi(f) = 0 \quad \text{f.f. ker } f \text{ is } \mathbb{R}^n, \text{ CTDR}$$

$\Leftrightarrow \forall x \in \mathbb{R}^{2n} \exists y \in \mathbb{R}^{2n} \quad f(x) = y$

$$S_{\tilde{t}}(f) = 0 \Rightarrow \varphi(f) = 0$$

$$\sum_{t=1}^T f(t) = 0 \Rightarrow \Psi(f) = 0 \quad f \in P_n$$

$$f(t_i) = 0 \quad \forall i \Leftrightarrow f = \pi_n \cdot g \quad g \in P_{n-1}$$

$$\pi_n(t) = (t-t_1) \dots (t-t_n) \quad \text{rec}$$

π_n は n 次の n 次の

$$\Psi(\pi_n \cdot g) = 0 \quad \text{rec}$$

$$l \leq n \quad g \in P_l \quad \text{は } l \text{ 次の}$$

π_n は n 次の

π_n は n 次の n 次の

は π_n は n 次の $n-1$ 次の

$(u, v) \mapsto \underline{\langle u, v \rangle} = \underline{\Psi(u \cdot v)}$ は n 次の

$a = -1, b = 1, \omega(t) \leq 1$.1 $\int_{\gamma} \int_{\Gamma} \int_{\Omega}$

35' $\int_{\Gamma} \int_{\Omega}$ $\rho' \partial(\gamma)$ \tilde{t}_n

$$\omega(t) = \frac{1}{\sqrt{1-t^2}}, a = -1, b = 1 - 2$$

π_n \subseteq $N \cap C_1$ t_i

$$\omega_i = \int_{(t-t_i) \cdot \pi_n^{-1}(t_i)}^{\pi_n(t)} w(t) dt$$

???

$w(t_i)$

$\Rightarrow T_{th}$ fe mehrere \exists -

, $\forall \epsilon / \exists N$

. $w_i > 0 \Rightarrow \exists \cdot z$

$\Rightarrow \exists \rho'_i / \text{curve } \rho'_i \cap S_2 = \rho_i$

$$w_i = \sum w_j l_i^2(t_j) \Leftrightarrow \underbrace{\int l_i^2 \omega dt}_{\geq 0} > 0$$

$E_n(f) \xrightarrow[n \rightarrow \infty]{} 0$, $f \in L^2$

, $p_i \xrightarrow[i \rightarrow \infty]{} f$ $\Rightarrow \exists \rho'_i$

- $i \rightarrow \infty \quad \rho'_i \cap S_2 = \rho_i$

$$|E_n(f)| = |E_n(f - P_{2n-1})| =$$

$$\left| \int_a^b (f - P_{2n-1}) \omega(t) dt - \sum_{i=1}^n w_i \cdot (f(\xi_i) - P(\xi_i)) \right| \leq$$

$$\left| \int_a^b (\underline{f - P}) \omega(t) dt \right| + \sum_{i=1}^n w_i |f(\xi_i) - P(\xi_i)| \leq$$

$$\|f - P\|_\infty \cdot \left(\underbrace{\int \omega(t) dt}_{\| \quad \|} + \underbrace{\sum w_i}_{\| \quad \|} \right) =$$

$$\underbrace{\|f - P\|_\infty}_{\| \quad \|} \cdot 2 \cdot M_0$$

17. 1730 \wedge 17. 1730

8. 1730 \wedge P_K \sim 1730

$V_K \subseteq V_{K+1}$ \wedge 1730

$\overbrace{\text{NP} \text{ P12} \text{ 27-} - V}$

$\psi: V \rightarrow \mathbb{R}$

$\theta = \varphi \circ \tilde{s}: V \rightarrow \mathbb{R}$

$E = \psi - \theta$

$P \in P_K$ \wedge $E P = 0$

$f \in C^k((0, 5], \mathbb{R})$

$$f(x) = \sum_{i=0}^k a_i x^i + \frac{1}{k!} \int_0^x (x-t)^k f^{(k+1)}(t) dt$$


$$E(f) = \frac{1}{k!} E \int_0^x (x-t)^k f^{(k+1)}(t) dt =$$

$$\frac{1}{k!} \in \mathbb{E} \int_0^b (x-t)_+^k f^{(k+1)} (+) dt$$

$$\frac{1}{k!} \int_0^b E((x-t)_+^k) f^{(k+1)}(t) dt$$

$$(x-t)_+ = \begin{cases} x-t & t \leq x \\ 0 & t > x \end{cases}$$

$$E(f) = \int_a^b K_k(t) f^{(k+1)}(t) dt \geq$$

$$K_k(t) \geq 0 \quad \forall t$$

$$\geq f^{(k+1)}(z) \cdot \int_0^1 K_k(t) dt$$

Numerical Linear Algebra

Folkmar Bornemann

A linear system of equations

$$A \bar{x} = b$$

row echelon form

row reduction

$$\begin{pmatrix} a & b \\ 0 & c \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}$$

$$c y = d_2 \Rightarrow y = \frac{d_2}{c}$$

$$A = \underbrace{L}_{\text{NLS}} U \quad \begin{cases} \text{IS} & \text{IBW} \\ \text{SIS} & \text{U} \end{cases} \quad \text{NLS}$$

این دست روشی است که
 $A = L U$

$$Ax = b \Rightarrow L U x = b \Rightarrow$$

$$Lc = b \quad \text{و} \quad Ux = c$$

که این دست روشی است که

برای مسکن فر

$$z^T A z \geq 0 \quad \forall z \in \mathbb{R}^n$$

$$L_1 V_1 = L_2 V_2 \Rightarrow L_2^{-1} L_1 = \underbrace{V_2 V_1^{-1}}_{(P)}$$

$$\underbrace{\begin{pmatrix} a & b \\ c & d \end{pmatrix}}_{\text{Knell}} = \begin{pmatrix} 1 & 0 \\ x & 1 \end{pmatrix} \begin{pmatrix} a & b \\ 0 & x \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 0 \\ x & 1 \end{pmatrix} \begin{pmatrix} a & b \\ 0 & x \end{pmatrix}$$

$[a \neq 0 \rightarrow \text{IJ}, a=0 \rightarrow \text{N}^T \cap \text{W}]$

$$Xa = c \Rightarrow X = \frac{c}{a}$$

$$bx + y = d \Rightarrow y = d - \frac{bx}{a}$$

$$A = L \cup =$$

$n \rightarrow$

$$(X | r_1) = (\alpha_1 | a_1)$$

$X = \alpha_1 \neq 0$

$\underline{l_1} = \underline{b_1 / \alpha_1}$

$B = L' \cup'$

$D \subset L', \exists \beta \in \mathbb{N} \text{ such that } \beta f \in C_{\text{near}}$

$$B = D' - l_1 r_1$$

23. Find $\lambda^3 \text{adj } A$, if $A = \begin{pmatrix} 1 & 2 & 3 \\ 2 & 1 & 3 \\ 3 & 3 & 1 \end{pmatrix}$

$$-l \quad \} \Rightarrow P$$

$$PA = LU$$

Find the row U such that

1. All off-diagonal entries in
each row $|x| \leq 1$ are positive for

$$L \rightarrow x \rightarrow \text{Gauss Elim}$$

$$\begin{pmatrix} 0 & 1 & 2 \\ 3 & 0 & 1 \\ 5 & 1 & 2 \end{pmatrix} = P_1 \cdot \begin{pmatrix} 5 & 0 & 3 \\ 3 & 0 & 1 \\ 0 & 1 & 2 \end{pmatrix} =$$

$$P_1 \begin{pmatrix} 1 & 0 & 0 \\ 3/5 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} 5 & 0 & 3 \\ 0 & 1 & 0 \\ 0 & 0 & 2 \end{pmatrix}$$

$$B = \begin{pmatrix} 0 & 1 \\ 1 & 2 \end{pmatrix} - \begin{pmatrix} 0 & 3/5 \\ 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & -4/5 \\ 1 & 2 \end{pmatrix}$$

$$\begin{pmatrix} 0 & -\gamma/\varepsilon \\ 1 & 2 \end{pmatrix} = P_2 \begin{pmatrix} 1 & 2 \\ 0 & -\gamma/\varepsilon \end{pmatrix}$$

$$P_1 \cdot \begin{pmatrix} 1 & 0 & 0 \\ 0 & P_2 \end{pmatrix}$$

$\overset{11}{P}$

$$A = \begin{pmatrix} \varepsilon & 1 \\ 0 & 0 \end{pmatrix} \quad 0 < \varepsilon$$

$| \Gamma \rangle$

$$= \begin{pmatrix} 0 & 1 \\ 1/\varepsilon & 1 \end{pmatrix} \underbrace{\begin{pmatrix} \varepsilon & 1 \\ 0 & 1 - 1/\varepsilon \end{pmatrix}}_{\sim} \sim$$

$$\begin{pmatrix} 1 & 0 \\ 1/\varepsilon & 1 \end{pmatrix} \begin{pmatrix} \varepsilon & 1 \\ 0 & 1 - 1/\varepsilon \end{pmatrix} = \begin{pmatrix} \varepsilon & 1 \\ 1 & 0 \end{pmatrix}$$

Cholesky

1.5

: $\lambda^* \lambda^* \geq 0$ $A = A^* - c \in \mathbb{R}^{n \times n}$

$\bar{x}^* A \bar{x} > 0$, $\bar{x} \neq 0$ for

$$\left((\bar{x}^* A \bar{x})^* = \bar{x}^* A^* \bar{x} = x^* A \bar{x} \in \mathbb{R} \right) \quad \text{s.t. } A = A^* \text{ s/c}$$

$(\bar{x}, \bar{y}) \mapsto \bar{x}^* A \bar{y}$

$\therefore \bar{x}^* \bar{y} = \bar{y}^* \bar{x}$

$\Rightarrow N \exists \bar{v} \in \mathbb{R}^n$ $\bar{v}^* \bar{v} = 1$ $\bar{v}^* A \bar{v} = 0$ s/c
 $\therefore \bar{v}^* A \bar{v} = 0$

sic nach A $\delta(\cdot)$ ist

positive für $0 < \sqrt{c} < 1$

negativ für $\sqrt{3} < \sqrt{c} < 2$

$\sqrt{2}/h \approx 1.4$

je 2 e' 150 $\approx 3^{\circ} C/f$ s/c

$$A = L \cup$$

$$A = A^* = U^* L^*$$

negative $\sqrt{c} > 2$ ist ~~neg~~
-er $\sqrt{2}/h$ ist positive

$$L^* = U$$

$$(U^* = L \text{ und } f)$$

$$A = L \cdot L^* \quad ? \quad ? \quad ? \quad e' \quad \text{pf}$$

Zurück zu den Lernzetteln

Zur Position für den Kurs

. . .

IN 1, 13th Turnier ~ 2000

, LU PZ

$$\begin{pmatrix} \alpha & a_1 \\ & a_2 \end{pmatrix} = \begin{pmatrix} \alpha & a_1 \\ b_1 & b_2 \end{pmatrix} \xrightarrow{\quad} \begin{pmatrix} \alpha & a_1 \\ b_1 & b_2 \end{pmatrix}$$

ר'ז'נַן אֶ-כְּרִיּוֹן

אָגָרְטָה

$A: K^m \rightarrow K^n$

$K = \mathbb{R}/\mathbb{C}$

ר'ז'נַן אֶ-כְּרִיּוֹן

$A = Q R$

פְּרִזְבֵּת

ר'ז'נַן אֶ-כְּרִיּוֹן Q פְּרִזְבֵּת

ר'ז'נַן אֶ-כְּרִיּוֹן R: $K^m \rightarrow K^{m'}$
ר'ז'נַן אֶ-כְּרִיּוֹן A ינטְגָרָט

ר'ז'נַן A^* A

$\Rightarrow \text{3IN3 } A^* A \underbrace{\text{ is inv.}}$

$\Rightarrow \|Ax\| = 0 \quad \text{SIC, } \Rightarrow \text{3f}$

$\bullet -x=0 \quad (\Rightarrow Ax=0)$

meric sic . y'n' n A-u n' j j

$A^* A = L \cdot L^*$ meric > 5

np' j . ? / Nen mehr L

$Q = A R^{-1} \quad ?/ ? \text{ , } R = L^*$

SIC. $Q^* Q = \text{Id} \sim \{ \}$

$Q^* Q = (R^{-1})^* A^* A R^{-1} = \underline{L^{-1} \cdot (L \cdot L^*) \cdot R^{-1}}$

$R \cdot R^{-1} = \text{Id.}$

Sei $A = Q, R,$ $\mathcal{S}_C, \mathcal{J}_L, \mathcal{B}_L$

$$A^T A = R_1^T Q_1^T Q_1 R_1 = R_1^T R_1$$

$$\begin{matrix} q' & n' \\ \nearrow & \searrow \\ \text{---} & \text{---} \end{matrix}$$

Wieder $Q = \{q'_1, q'_2, \dots, q'_n\}$

Wieder $R = \{r_1, r_2, \dots, r_n\}$

Wieder $Q = \{q'_1, q'_2, \dots, q'_n\}$

$$A = Q \cdot R \Leftrightarrow \underbrace{A \cdot R^{-1}}_{= Q} = Q$$

$$R^{-1} = \begin{pmatrix} \alpha & \beta & \cdots \\ r & \ddots & \cdots \end{pmatrix}, \quad A = (a_1, \dots, a_n)$$

$$\alpha = \frac{1}{\|a_1\|}, \quad \beta = a_1 + \gamma a_2$$

$$A = (a_1, \dots, a_n)$$

: $\mathbb{R}^n \rightarrow \text{Vect}$

$A = Q \cdot R = \underbrace{\overline{Q}}_{Q_1 \cdot R_1 + (Q_2, \dots, Q_n) R'}$

$$Q = (q_1, \dots, q_n)$$

$$A = Q R$$

$$R = \begin{pmatrix} \rho & \bar{r} \\ 0 & R' \end{pmatrix}$$

$$Q^T A = R$$

$$(a_1, \dots, a_n) = (q_1, \dots, q_n) \cdot$$

$$\rho \cdot q_1 = a_1 \Rightarrow \rho = \|a_1\|, \underline{q_1 = a_1 / \rho}$$

$$q_1 \cdot a_i = r_i \quad Q \cdot A = (\rho, \bar{r})$$

$$\therefore \exists g \in Q \cap \mathbb{Z}^n \quad \left\{ \begin{array}{l} g \in \text{range}(Q) \\ g \cdot a_i = r_i \end{array} \right. \quad Q \cdot g = \rho$$

$$A - g \cdot r_i = Q' \cdot R'$$

数值解法 为 线性方程组

收敛性

$$(A \in \mathbb{R}^{n \times n}) \quad Ax = b$$

$$\text{cond}(A) = k(A)$$

$$k(A) = \|A^{-1}\| \cdot \|A\|$$

b 为系数矩阵 A 的右端项 - b*

$$\frac{\|b^* - b\|}{\|b\|}$$

$$\frac{\|A^{-1}b^* - A^{-1}b\|}{\|A^{-1}b\|} = \frac{\|A^{-1}(b^* - b)\|}{\|A^{-1}b\|} \leq \frac{\|A^{-1}\| \|b^* - b\|}{\|A^{-1}b\|} =$$

$$\frac{\|A^{-1}\| \cdot \|b\|}{\|A^{-1}b\|} \cdot \frac{\|b^* - b\|}{\|b\|} = \frac{\|A^{-1}\| \cdot (\|A \cdot A^{-1} \cdot b\|)}{\|A^{-1}b\|} \cdot \frac{\|b^* - b\|}{\|b\|} \leq$$

$$\leq \kappa(A) \cdot \frac{\|b^* - b\|}{\|b\|}$$

$$\|Av\| \leq (\|A\| \cdot \|v\|)$$

$$\|A\| = \sup_{v \neq 0} \frac{\|Av\|}{\|v\|} = \sup_{v \in C} \|Av\|$$

$A \in \mathbb{R}^{n \times n}$

$$\frac{\|\tilde{A}^{-1}b - \tilde{A}'^{-1}b\|}{\|\tilde{A}'^{-1}b\|} = \frac{\|\tilde{A}' \cdot \tilde{A} \tilde{A}'^{-1}b - \tilde{A}' \cdot \tilde{A} \tilde{A}'^{-1}b\|}{\|\tilde{A}'^{-1}b\|} =$$

$$\frac{\|A'(\tilde{A} - A)\tilde{A}'^{-1}b\|}{\|\tilde{A}'^{-1}b\|} \leq \|A'\| \|A - \tilde{A}\| \|\tilde{A}'^{-1}b\|$$

$$\frac{\|A'\| \cdot \|A\| \cdot \|\tilde{A} - A\|}{\|A\|} = \kappa(A) \cdot \frac{\|\tilde{A} - A\|}{\|A\|}$$

$$\|ABv\| \leq \|A\| \|Bv\| \leq \|b\| \|B\| \|v\|$$

: (Kahan) NYC

$$\frac{1}{\kappa(A)} = \min \left\{ \frac{\|A - \tilde{A}\|}{\|A\|} \mid \begin{array}{l} \text{for } \tilde{A} \\ \text{such that} \end{array} \right\}$$

, נס'ה ו'ז'ז ל'ז'

$$\frac{\|A - \tilde{A}\|}{\|A\|} \geq \frac{1}{\|A\| \cdot \|\tilde{A}'\|}$$

$\rightarrow \sqrt{3} \approx \sqrt{6}$

$$\|\tilde{A}'\| \cdot \|A - \tilde{A}\| \geq 1$$

$\delta \omega / \zeta$

$$\|A^{-1}\| \cdot \|A - \tilde{A}\| \geq \|A^{-1}(A - \tilde{A})\| =$$

$$\|I - A^{-1} \tilde{A}\|$$

$$\sim c \quad \sqrt{\text{cond}} \quad \begin{matrix} \text{down} \\ \nearrow \searrow \end{matrix} \quad \text{se}$$

$$\|I - A^{-1} \tilde{A}\| \geq 1$$

$\exists c \quad 0 \neq v \in \ker(A) \subset \mathbb{R}^n$

$$\|I - A^{-1} \tilde{A}\| \geq \|(I - A^{-1} \tilde{A})v\| / \|v\| = \frac{\|v\|}{\|\tilde{A}v\|}$$

\Rightarrow v' ist rcf \tilde{A} ≤ 3 Δ

$$\|A - \tilde{A}\| = \frac{1}{\|A^{-1}\|}$$

$$w = A^{-1}v, \|A^{-1}v\| = \|A^{-1}\| \quad \begin{matrix} \sim c \\ \nearrow \searrow \end{matrix} \quad \checkmark \quad \begin{matrix} 1 \\ \|v\|=1 \end{matrix}$$

per sen V dann nur mehr J

$$\tilde{A} w = 0 \quad \gamma' \beta \beta' \omega - \delta$$

$$A|_U = A|_{U^{-1}}$$

$$\underbrace{\|A - \tilde{A}\|}_{\|w\|} \|\tilde{A} \cdot w\| = \|v\| \underbrace{\|A^{-1}v\|}_{\|w\|}$$

$$\frac{1}{\|A^{-1}\|}$$

$$\sup_{\substack{\|cw+u\|=1 \\ u \in U}} \|(A - \tilde{A})(cw + u)^*\| = \sup_{\|cw\|=1} \|(A - \tilde{A})cw\| =$$

$$\sup_{\|cw\|=1} \|Aw\| = \frac{\|Aw\|}{\|w\|}$$

প্রার্থনা করা হৈ

মনসা'র প্রয়োগ নির্বাচন $\sim f$

প্রার্থনা করা - f

এ' একে, য স্বত্ত্ব

~~$f(y) = f(y^*)$~~

-e } y^*
 $(y \text{ ফলীগু)$

মনসা'র করা, কোন কু এ'

cond(f)(y) } নির্বাচন করা

প্রেরণ করা কু

$a^* b = a^* \cdot b$ কু

• $\lambda \circ f \circ g$: $\mathbb{R}^n \rightarrow \mathbb{R}^m$ injektiv

$\gamma \Gamma \vdash P \quad \exists' x \in C \quad \lambda b \rightarrow \nu$

$\frac{\lambda x' z' \quad \lambda (f) r \in}{__}$

$\exists' z' \exists r \in \int \lambda x \in C \quad f \circ$

$$\begin{pmatrix} a \\ b \end{pmatrix} \hat{\cdot} (c d) = \begin{pmatrix} * & * \\ * & * \end{pmatrix} + \begin{pmatrix} a \\ b \end{pmatrix} \cdot (cd)^*$$

$\text{det} \neq 0$

 — — —

$$\underbrace{f = h \circ g}_{\rightarrow \cup} \quad \wedge \quad \wedge' \cup$$

(1) $\lambda x \lambda y \lambda z \delta_{x,y} \delta_{y,z}$

$$\overline{f = h \circ g} \quad \delta_{x,y} \delta_{y,z} = f$$

$\mathcal{N}(x^*)$ of $\mathcal{M} \cap \mathcal{S}_{\lambda^*}$ if

$\nabla f(x^*)$ is non-zero.

then $f^{-1}(g(\mathcal{S}_{\lambda^*}))$ is non-empty.

$\nabla f(x^*)$ is zero.

Proof of $\mathcal{M} \cap \mathcal{S}_{\lambda^*} \neq \emptyset$

$\|\lambda^*\|_{L^2}$

Suppose x^* is a point in $\mathcal{M} - \mathcal{X}$

$$y^* = \tilde{x}, \quad \hat{f}(y) = \tilde{x}$$

Then $y^* \in \mathcal{S}_{\lambda^*}$

$$\omega(\tilde{x}) = \min \left\{ \frac{\|\tilde{x} - A\|}{\|A\|} \mid \tilde{x} = b \right\} =$$

$$\min \left\{ \frac{\|E\|}{\|A\|} \mid (A+E)\tilde{x} = b \right\}$$

Rigal-Gachers) diryc

$$W(\tilde{x}) = \frac{\|b - Ax\|}{\|A\| \|x\|}$$

AN/3 AN/7

અને કોઈ માત્રા

$$\frac{\|\mathbf{x} - \tilde{\mathbf{x}}\|}{\|\tilde{\mathbf{x}}\|} = \frac{\|\mathbf{A}'\mathbf{b} - \mathbf{A}'\mathbf{x}\|}{\|\tilde{\mathbf{x}}\|} \leq$$

$$\frac{\|A^{-1}\| \cdot \|b - Ax\|}{\|\tilde{x}\|} = k(A) \cdot w(\tilde{x})$$

દ્વારા કે ઉપરાંતે એવી વિધિ,

$$f = \underline{\underline{h}} \circ \underline{\underline{g}}$$

જે

$$\underline{\underline{g(A)}} = \begin{pmatrix} \underline{\underline{m}}, \underline{\underline{N}} \end{pmatrix}, \quad m \cdot N = A$$

$$\underbrace{h(m, n, b)}_{-/-} - \text{સાધારણ પોંગ}$$

નિચેનું
 $\checkmark - h$

ને આવું હોય તો એવી વિધિ કે
નું હોય તો એવી વિધિ કે
નું હોય તો એવી વિધિ કે

جذب الماء

جذب الماء

$$\frac{\|\tilde{M} \cdot \tilde{N} - M \cdot N\|}{\|M \cdot N\|} =$$

$$\frac{\|\tilde{M} \cdot \tilde{N} - M \tilde{N} + M \tilde{N} - M \cdot N\|}{\|M \cdot N\|} \leq \sqrt{\frac{\|\tilde{M} - M\|^2}{\|M\|^2} + \frac{\|\tilde{N} - N\|^2}{\|N\|^2}}$$

$$\|\tilde{M} - M\| \cdot \|\tilde{N}\| + \|M\| \|\tilde{N} - N\|$$

$$\frac{\|\tilde{M} - M\| \cdot \|N\| \|\tilde{N}\| + \|M\| \|\tilde{N}\| \cdot \|\tilde{N} - N\|}{\|M \cdot N\|} = 2 \cdot \frac{\|M\| \|\tilde{N}\| \|\tilde{N} - N\|}{\|M \cdot N\|}$$

ר 3 נג 'ונ' ו'ג' ז'ג' ר'ג'

: ג'ג' ג'ג' ג'ג'

$M, N \mapsto M \cdot N$

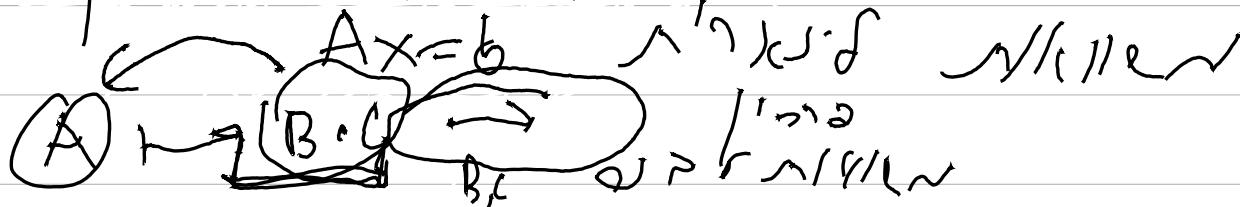
$$\begin{array}{l} \boxed{\|M \cdot N - M \cdot N\|} \\ \quad \quad \quad \|M \cdot N\| \end{array} = \begin{cases} \tilde{M} = (\tilde{x} - x) + u \\ \tilde{N} = (\tilde{v} - v) + v \end{cases}$$

$$\|(\tilde{M} - M) \cdot (\tilde{N} - N)\| \leq M(\tilde{N} - N) + (\tilde{M} - M) \cdot N + M \cdot N - M \cdot N$$

$$\underbrace{\|M\| \|\tilde{N} - N\|}_{\|N\| \cdot \epsilon} + \underbrace{\|M - \tilde{M}\| \|N\|}_{\|M\| \cdot \delta} \leq 2 \|M\| \cdot \|u\| \cdot \epsilon$$

$$K(\frac{\sqrt{\epsilon}}{M \cdot N}) = \frac{2 \|M\| \|u\|}{\|M \cdot N\|}$$

ל'ג'ג' ג'ג' ג'ג' ג'ג' ג'ג' ג'ג'



reflex R \rightarrow L(C) $\underbrace{A = Q \cdot R}_{\text{def}}$

\rightarrow $\Sigma P \hookrightarrow \Sigma / (Q \rightarrow \rightarrow)$

$\|QR\| = \|R\| \in \Sigma \Sigma P \hookrightarrow / (Q$

$(L_2 \cup \Sigma^{\Sigma P})$

$\|QRv\| = \|Rv\|$

$\|Q\| = 1$

$\Sigma \Sigma P \hookrightarrow \Sigma \Sigma P \cup Q$

$A = \underline{R^T} \cdot R$

\rightarrow $\Sigma P \hookrightarrow \Sigma \Sigma P \cup Q$

$\|A\| = \begin{cases} \Sigma P \\ \Sigma P \end{cases}$

$$\|A\| = \sqrt{\|A^T A\|} = \sqrt{\max_{\mathbf{v}} \langle \mathbf{v}, A^T A \mathbf{v} \rangle} = \sqrt{\max_{\mathbf{v}} \langle A \mathbf{v}, A \mathbf{v} \rangle}$$

$$R = R^T R$$

$$\|R\|^2 = \|R^T R\| = \|A\|$$

$$\|A\|^2 = \max_{\|\mathbf{v}\|=1} \langle A\mathbf{v}, A\mathbf{v} \rangle =$$

$$\max \langle A^T A v, v \rangle$$

achieve U , $A = L U$.
 If L is lower achieve L , \approx if

for i

: (vn and > for QR and \mathbb{R}^n)

• $u_1, u_2, u_3, \dots \in U, \langle , \rangle$

$v_1, v_2, v_3, \dots \in V$ k(B) \rightarrow \mathbb{R}

$$\langle v_i, v_j \rangle = \delta_{ij} \cdot \text{[c]}$$

$$\underbrace{\langle u_1, \dots, u_i \rangle}_{\rightarrow} = \langle v_1, \dots, v_i \rangle \quad , i \in [1, n]$$

$$A = (u_1, \dots, u_n) \quad | \quad \overbrace{\begin{aligned} w_1 &= \langle e_1 \rangle \\ w_2 &= \langle e_1, e_2 \rangle \\ w_3 &= \langle e_1, e_2, e_3 \rangle \end{aligned}}^{\text{N/C}}$$
$$Q = (v_1, v_2, v_3, \dots)$$

matrix form Q : /C

('ro \Rightarrow \mathbb{R}^n \rightarrow \mathbb{R}^m W
if $w_1 \subseteq w_2 \subseteq \dots \subseteq w_n = W$

$$A, Q : W \rightarrow U$$

$$A w_i = Q w_i \quad i \in \mathbb{N}$$

$$A \sim B$$

fin A, B
imp J.

$$\text{def } \underbrace{A w_i = B w_i}_{\text{sic}}$$

$$\text{sic } \underbrace{A \sim B}_{\text{sic}}$$

$$\text{sic } \underbrace{A = B R}_{\text{sic}} \quad \text{sic } \beta \gamma$$

$$R w_i = w_i \quad \text{sic } R : W \rightarrow \mathbb{C}^n$$

$$R = \underbrace{B^{-1} A}_{\text{sic}}$$

$$\boxed{A = Q R \Rightarrow \overline{Q} = \underline{A} \underline{R^{-1}}}$$

$$U_1 \mapsto U_1 / \mu_{U_1, 1} \quad \left(\frac{\mu_{U_1, 1}}{\dots} \right)$$

$$Ax = b$$

→ 대상이 \mathbb{R}^n 의 벡터 x

$$A: \mathbb{R}^n \rightarrow \mathbb{R}^m \quad m \geq n$$

only if x is a solution

$$\|Ax - b\|$$

이유

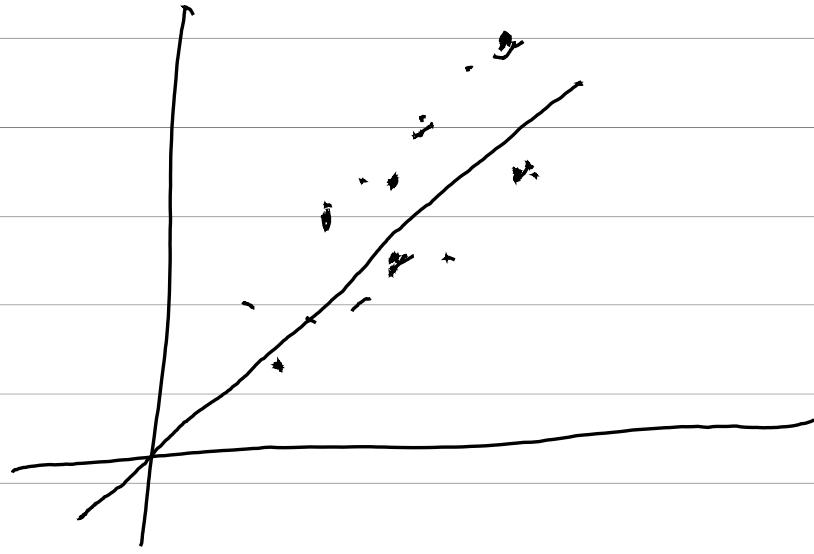
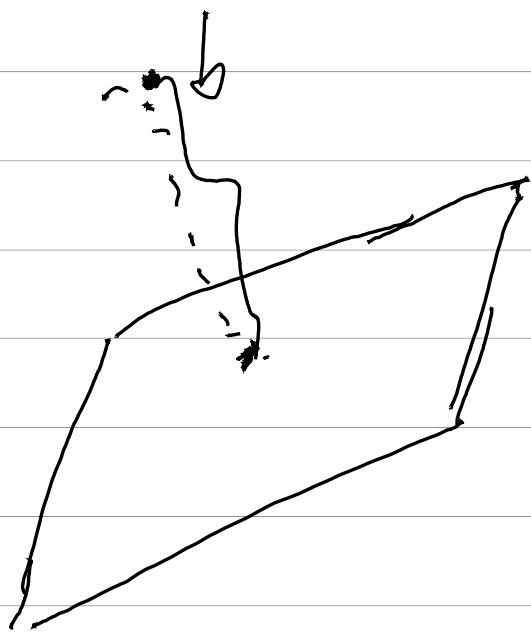
이제 A 가 단위행렬 Ax

인 경우 A 에 대한 단위행렬 Ax

$$-b - f \text{ 만족}$$

$$A = \underbrace{\begin{pmatrix} 1 & 1 & \dots & 1 \end{pmatrix}}_n, \quad n=1 \text{ 일 때 ?}$$

$$x = b_i + \underbrace{x}_{\text{new}} \quad \text{new } x$$



ئىچىرىدىكىلىرى پىزىتىرىسى

ئىچىرىدىكىلىرىسى

$$\underbrace{A^T A}_{\text{matrix}} x = \underbrace{A^T b}_{\text{vector}}$$

ئىچىرىدىكىلىرىسى

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ئىچىرىدىكىلىرىسى

ئىچىرىدىكىلىرىسى

$$\kappa(A) = \|A\| \cdot \|\underline{A^{-1}}\| = \sqrt{\|A^T A\|} \cdot \sqrt{\|(A^T \cdot g)\|} =$$

$$\sqrt{\kappa(A^T A)}$$

$$A = \begin{pmatrix} 1 & 1 \\ \varepsilon & 0 \\ 0 & \varepsilon \end{pmatrix} \quad b = \begin{pmatrix} 2 \\ \varepsilon \\ \varepsilon \end{pmatrix}$$

$$Ax = b \Rightarrow x = (1, 1)$$

$$A^T A = \begin{pmatrix} 1 & \varepsilon & 0 \\ 1 & 0 & \varepsilon \\ 0 & \varepsilon & \varepsilon \end{pmatrix} \begin{pmatrix} 1 & 1 \\ \varepsilon & 0 \\ 0 & \varepsilon \end{pmatrix} =$$

$$\begin{pmatrix} 1+\varepsilon^2 & 1 \\ 1 & 1+\varepsilon^2 \end{pmatrix}$$

$$k(A^T A) = 1 + \frac{2}{\varepsilon^2}$$

$$k(A) = \frac{\sqrt{2}}{\varepsilon}$$

$\Leftarrow \|A^T A\| = \max \left((1-(1+\varepsilon^2))^2 - 1 \right)$

$$\begin{pmatrix} a & 1 \\ 1 & a \end{pmatrix} \quad \text{det} \quad 1+a \quad \frac{\varepsilon^2}{\varepsilon^2} \approx 1$$

$\tilde{Q}^T R x - \omega$ for $\tilde{Q}^T R \tilde{x}$

$$A = QR \Rightarrow$$

~~some notes~~

$$\underbrace{A^T A}_{\cong} x = A^T b = P^T Q^T b$$

"

$$R^T \underbrace{Q^T Q}_{I} R x = P^T R x$$

$$R x = \underbrace{Q^T}_{\cong} b$$

so R is invertible

$$x + \sum a_i x^i = 0$$

\rightsquigarrow

$$\begin{pmatrix} 0 & -a_n \\ 1 & -a_1 \\ 0 & \vdots \\ 1-a_n & \end{pmatrix}$$

limits and continuity the

arc $\approx 3\pi$ $\approx \pi$ $\approx 3\pi$ $\approx \pi$

$\approx 3\pi$, $\approx \pi$ $\approx 3\pi$ $\approx \pi$)

length

area of \approx / area of

$\sqrt{1 + A^2} / 0.02 \int L / 1 \approx 50$

area of \approx

$$A_1 = Q^* A Q$$

$$\begin{pmatrix} 1 & 0 \\ 0 & \pi \end{pmatrix}$$

$$A_1 = \begin{pmatrix} \alpha & \cdots \\ 0 & \boxed{A} \end{pmatrix}$$

$$(x, a_1, \dots, a_n)$$

$$\alpha x + \dots = \mu x \quad \alpha \neq \mu \quad \checkmark$$

$$A = Q^T U Q$$

Schur decomposition

$$(A^T A) \quad A^T A = A^T A^T \quad \text{or}$$

$$A^T A = U \quad \text{or}$$

$$U = Q A Q^T$$

$$U^T U = Q A^T \underbrace{Q^T Q}_A Q^T = Q A^T A Q^T.$$

$$Q A^T A Q^T = \underline{\underline{U^T}} \Rightarrow$$

$$U_{\text{NSP or IC}}$$

λ , ν $\in A \cap \mathbb{N}$ $\forall n$
 $\lambda > n$
 $\nu < n$

$\lambda > n$ ν $n > \lambda$ ν $\tilde{\lambda}$

$\tilde{\lambda}$ $n > \lambda$

$|\tilde{\lambda} - \lambda|$
~~Diagram showing two overlapping circles with a horizontal line segment between them.~~

$\|\tilde{\lambda} - \lambda\|_*$
~~Diagram showing a circle with a horizontal line segment through its center, labeled with $\|\lambda\|$.~~

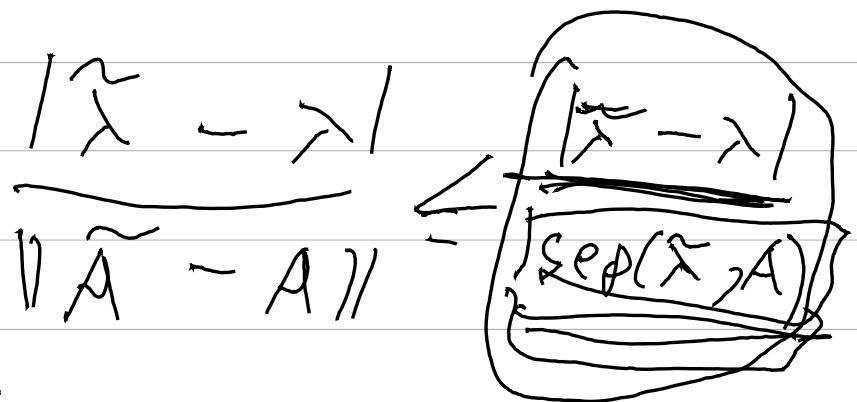
$\tilde{\lambda}$

$$\begin{aligned}
 \omega &= \min \left\{ \|\lambda - \tilde{\lambda}\| \mid \right. \\
 &\quad \left. \|(X\mathbb{I} - X^*) - (X\mathbb{I} - \lambda)\| \right\} \\
 &\quad \Downarrow \\
 &\quad \text{between } \mathbb{I} \text{ and } X\mathbb{I} - \tilde{\lambda}
 \end{aligned}$$

$$\alpha = d(\tilde{\lambda}I - A, \text{range } \tilde{A}) =$$

$$\| \tilde{\lambda}I - A \| = \underbrace{\text{sep}(\tilde{\lambda}, A)}_{\text{rec}} = \underbrace{\| (\tilde{\lambda}I - A)^{-1} \|}_{\text{rec}}$$

$$\text{sep}(\tilde{\lambda}, A) \left(= 0 \text{ rec} \right)$$



$$\| (\tilde{\lambda}I - A)^{-1} \|$$

μ 'n3y p3o, 'n3y r'f3 / v

$$(\lambda I - A)v = \lambda v - \underbrace{Av}_{(\lambda - \mu)v} =$$

$$(\lambda I - A)^{-1}v = \frac{1}{\lambda - \mu}v$$

$$\|(\lambda I - A)^{-1}\| \geq \left| \frac{1}{\lambda - \mu} \right|$$

$$\|(\lambda I - A)^{-1}\| \geq \underbrace{\frac{1}{d(\lambda, \sigma(A))}}$$

$$\sigma(A) = \left\{ \lambda \in \mathbb{C} : \exists \underbrace{\text{non-zero } v \in \mathbb{C}^n}_{A} \right\} \stackrel{\cong}{\sim} \overline{\text{sep}(\lambda, A) \leq d(\lambda, \sigma(A))}$$

$$A = \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \quad : \text{ (well) } ?$$

$$\sigma(\lambda, \sigma(A)) = \{\lambda\}, \quad \delta(A) = \{0\}$$

$$(\lambda I - A)^{-1} = \begin{pmatrix} \lambda^{-1} & -1 \\ 0 & \lambda \end{pmatrix}^{-1} =$$

$$\begin{pmatrix} \frac{1}{\lambda} & \frac{-1}{\lambda^2} \\ 0 & \frac{1}{\lambda} \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \frac{x}{\lambda} + \frac{y}{\lambda^2} \\ \frac{y}{\lambda} \end{pmatrix}$$

$$\|(\lambda I - A)^{-1}\| \underset{\lambda \rightarrow 0}{\sim} \frac{1}{|\lambda|^2}$$

$\text{src} \rightarrow \text{start } A \text{ at } \underline{\text{size}}$

$$\underline{\text{Sep}}(\alpha, A) = d(\alpha, \sigma(A))$$

$\overbrace{\text{end of } A}$ $\overbrace{\text{start of } A}$ $\overbrace{\text{end of } A}$

$\text{in } C \text{ if } C \text{ is } ? \text{ for }$

$\text{and then if } C \text{ is } ? \text{ do } C$

$\text{end if } C \text{ is } \text{while } \text{do } C$

$\text{if } C \text{ is } A - c \text{ then }$

$\text{end if } C \text{ is } \text{if } C \text{ do } C$

$\text{if } C \text{ is } ? \text{ then } C \text{ do } C \text{ end if } C$

surrounds A, now,

(1) $x \sqrt{y} \in \mathbb{Q} \cdot A = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \underbrace{\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}}_{3}$

112) $\text{HS} \rightarrow \text{S}$ $\text{HCl} \rightarrow \text{H}_2\text{S}$ $\text{H}_2\text{O} \rightarrow \text{H}_2$

• \exists $C \in A \rightarrow P' \sim \emptyset$

רְנֵנָה יְמִינָה מִזְבֵּחַ

. p'3~N 35 ~-)

~~(x, y)~~ \rightarrow x^y

‘NBY’ ‘NGP’ ‘NBY’ JAS

לנובמבר - וויליאם פון גיריגס

$$P(V) = \{ l \mid l \subseteq V \}$$

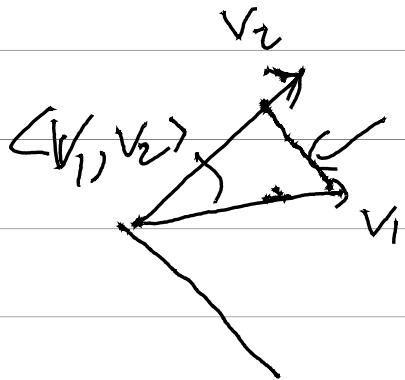
$$d(l_1, l_2)$$

7'30'

\Rightarrow 두 선분의 시인적 거리

$$l_1 = \langle v_1 \rangle, \quad l_2 = \langle v_2 \rangle$$

$$\|v_1\| = \|v_2\| = 1$$



$$w \in l_1^\perp \quad w \in$$

$$\|\pi_w(v_1)\| = d(l_1, l_2)$$

$$1 = \frac{\langle v_1, v_2 \rangle^2}{\|v_1\|^2} = \frac{\cos^2 \alpha}{\underbrace{(\|v_1\|^2 - \langle v_1, v_2 \rangle)}_{\text{projection length}}}$$

$\gamma^1 \delta_N \cap A \subset \underline{\text{inv}}$

$\omega \rightarrow \text{inv}$ } \Rightarrow γ^1

$$d(\tilde{\ell}, \ell) \leq \frac{\|\tilde{A} - A\|}{\text{dist}(\tilde{\ell}, \sigma(A)\cap)}$$

\leq

For ω s.t. $\tilde{\ell}$ rec

$\cdot \lambda$ inv } \Rightarrow \tilde{A}

$$\omega = \ell^\perp \quad \int_{\mathbb{R}^N} \text{inv}$$

, $\tilde{v} \in \tilde{\ell}$ \Rightarrow $f_n \circ \pi_w : V \rightarrow W$

$$\|\tilde{v}\| = 1$$

$$\pi_w(\tilde{A} - A) \tilde{v} = \pi_w(\tilde{X} \tilde{v} - Av) =$$

$$\pi_w(\tilde{X} \tilde{v} - A|_w \pi_w(v)) =$$

$(\tilde{X} \tilde{I} - A|_w) \pi_w(v)$

$$\pi_w(v) = (\tilde{X} \tilde{I} - A|_w)^{-1} \pi_w(\tilde{A} - A)v$$

$$d(\ell, \tilde{\ell}) = \|\pi_w(v)\| \leq \|(\tilde{X} \tilde{I} - A|_w)^{-1}\|.$$

$\|\pi_w\|, \|A - A|_w\|$

$\|_{\text{sep}}(x, P|_w) =$

$\bullet V = \ell \oplus w$

$A|_\ell \subseteq \ell, A|_w \subseteq w$

$\frac{1}{\text{dist}(x, \overline{r(A)_w})}$

$r(A) - \{x\}$

רְבָרְבָרָה אֲמַרְתִּי וְאַתָּה
וְאַתָּה כָּלֵב אֶלְעָזֶר

$$\underbrace{P(A)}_{\text{Probability}}(\ell) = A(\ell)$$

לְמִזְרָחַתּוֹ וְלְמִזְרָחֵלָה וְלְמִזְרָחַתּוֹ וְלְמִזְרָחֵלָה

$P(A)$ \subseteq $\mathcal{P}(\Omega)$

312 ~ 200 P(A) PC

177 143 720 50

• N'3nC'c '?' & ~

Real numbers } > 0 i.e. \mathbb{R}^+ \cup $\{0\}$ \cup $\{n \in \mathbb{N} : n > 0\}$

For every $\exists \forall$ \neg

For $\rho' \omega / \alpha$ there is no \sim

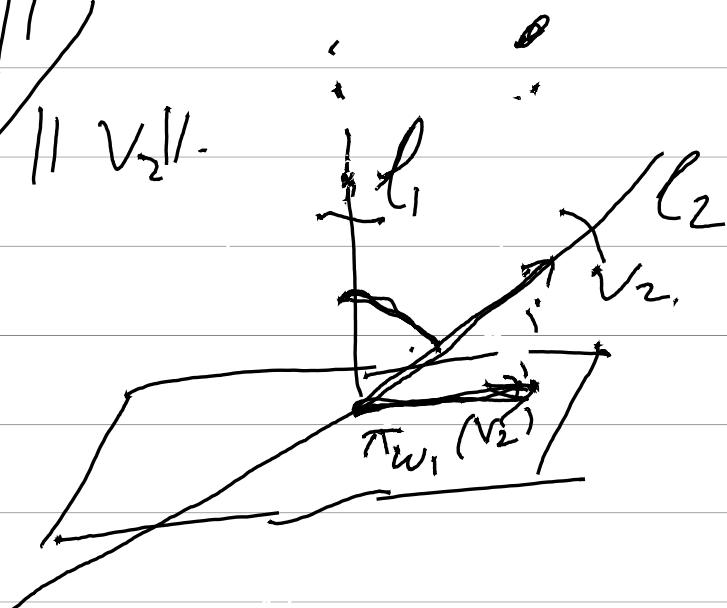
in $\beta c \geq \lambda \gamma \sqrt{d}$

$$\left[\sqrt{a^n + b^n + c^n} \right] \approx A^k v_0 = \frac{(x_1)}{1 \lambda_2}$$

$d(l_1, l_2) \neq v_2 \in l_2$

$$\|\pi_{w_1}(v_2)\|$$

$$\|v_2\|.$$



$$w_1 = l_1^\perp$$

$$A: V \rightarrow V$$

$$|\lambda_1| > |\lambda_2| \geq \dots \geq |\lambda_n| \quad \text{w/c}$$

$$\ell_1, \dots, \ell_n \quad \text{are eigenvectors} \quad \lambda_i$$

$$\cdot \sim |c_{\lambda}| \sim \sim \sim \sim \sim \sim$$

$$[A^* v_0] \rightarrow \ell_1, \dots, \ell_n \perp v_0$$

$$\underbrace{\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_n}_{n} \quad \ell_1 = \bigoplus_{i=1}^n \ell_i \quad \left(\frac{|\lambda_2|}{|\lambda_1|} \right)$$

$$\underline{A^* A = A A^*} \quad \therefore \text{rank } A \leq n$$

$$\text{rank } A \leq n \quad (\Rightarrow) \quad \text{rank } A \leq n$$

$$A = Q D Q^{-1} \quad \text{rank } A \leq n \quad \text{rank } Q \leq n$$

$$SC \quad A = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \underbrace{\text{basis}}$$

$$A^k \cdot \begin{pmatrix} x \\ y \end{pmatrix} = \begin{cases} \begin{pmatrix} x \\ y \end{pmatrix} & \text{if } s \leq k \\ \begin{pmatrix} x \\ -y \end{pmatrix} & \text{if } s > k \end{cases}$$

প্রদর্শন করুন। SC $x, y \neq 0$ এর

$$[A^k \begin{pmatrix} x \\ y \end{pmatrix}]$$

অসম রেফ



বিন্দুর সংজ্ঞা বিভাগ পর

সূচিতে দেখুন কিন্তু

বিন্দুর সংজ্ঞা $\|A\tilde{v} - \lambda\tilde{v}\|$ হলো

$\lambda = \langle \tilde{v}, A\tilde{v} \rangle$

$\|v\| = 1$

" $\|v_{k+1}\|$ " $v_0 - \sqrt{\lambda} \in \text{span}$

" $\|v_{k+1}\|$ " $\approx \sqrt{\lambda}$

$$w_{k+1} = A v_k$$

$$v_{k+1} = \frac{w_{k+1}}{\|w_{k+1}\|}$$

$$\mu_{k+1} = \langle w_{k+1}, A w_{k+1} \rangle$$

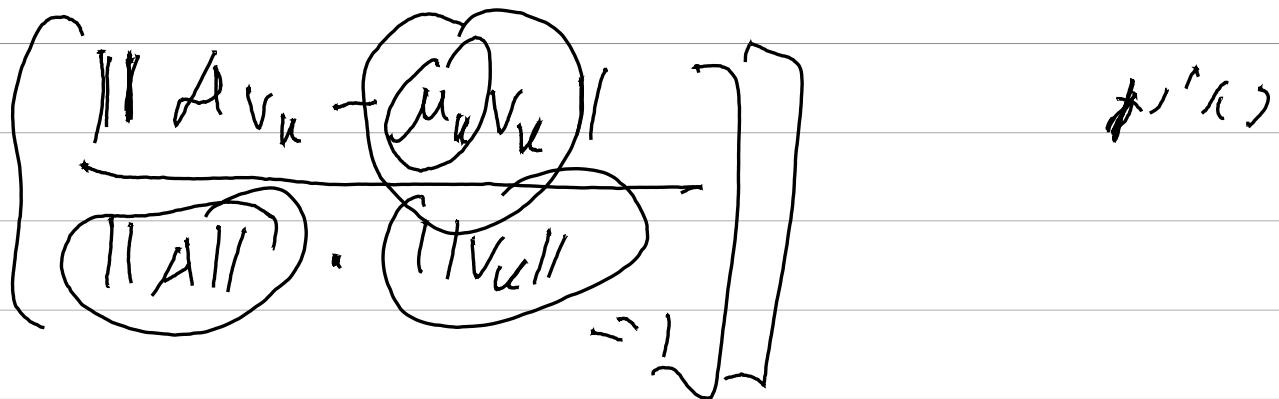
? $\geq 13\% \approx$

$\approx 10\% \geq 13\%$, $\epsilon > 0 \approx 10\%$

$$\tilde{A} v_k = \mu_k v_k - e \quad \Rightarrow \quad \tilde{A} e' \\ \cdot \frac{\|A - \tilde{A}\|}{\|A\|} < \epsilon \quad \rightarrow$$

γ_{RC} γ_{BDF} $\sim 3/7$ S_C

$$\gamma > \min \left\{ \frac{\|A - \tilde{A}\|}{\|A\|} \mid \tilde{A}^T v_k = \mu_k v_{k_p} \right\} = b$$



γ_{RC} S_C ≈ 1.712 ≈ 5

$$\|A\|_2 \approx \sqrt{\lambda_{\max}(A)}$$

$$\log \left(|\lambda_1| \approx 10^{-6} \text{ Hz} \right)$$

• γ_{RC} $\approx 10^{10}$ $\approx 10^{10}$ $\approx 10^{10}$

$$\left(\frac{\|A\|_2}{\|A\|_1} \approx 10^{-6} \cdot 10^{-2} \right) \cdot 10^{10}$$

$A \rightarrow \delta I$ $A - \mu I$ $-f$ is eigenvector

$\lambda - 1$ probability $\approx 1/10$

$\lambda - \mu$ rest A for 'rest' \rangle^{rest}

$A - \mu I$ for \rangle^{rest}

$$Av = \lambda \underbrace{v}_{(A - \mu I)v = \lambda v - \mu v =}$$

$$(\lambda - \mu) \underbrace{v}_{(A - \mu I)^{-1} v = \frac{1}{\lambda - \mu} v}$$

$$(A - \mu I)^{-1} v = \frac{1}{\lambda - \mu} v$$

1 in probability $\approx 1/10$ chance $\approx 1/10$

'rest' \rangle^{rest} , $(A - \mu I)^{-1}$



$$-c > \mu - \lambda_1 < \mu - \lambda_2 < c$$

$$|\lambda_1 - \mu| < |\lambda_2 - \mu| \leq \dots$$

then σ/ϵ defines $\sigma_{\text{eff}}/\epsilon$

γ of $\lambda_1 - \gamma$ is called γ

$$(A - \lambda I)^{-1} \quad \text{if } \lambda \neq \lambda_1, \lambda_2$$

$$\text{and } \lambda_1, \lambda_2 \text{ are eigenvalues}$$

$$(A - \lambda I) \underline{w}_k = v_k \quad \text{for } k \neq 1$$

$$\frac{1}{v_k - \lambda}$$

$$d_{k+1} = \langle v_{k+1}, A v_k \rangle^{-1}$$

$$v_{k+1} = \underline{w}_{k+1} / \|w_{k+1}\|^2$$

$$\cancel{(A - \mu I)} \underline{x} = \underline{b}$$

→ 2' 3' | 8 2' 8 2 | 1 2 1 1 0 0

UNIC 1976 (1976) 15

151 'n' 2 2 2 2 2 2 2 2

X - i

Q R non si sic

$$\begin{pmatrix} * \\ 0 & \dots & 0 \end{pmatrix} = R = Q^* A Q$$

• \Rightarrow für mehr

$$\hookrightarrow 030 \quad 113 \text{ns} \quad \sim 3/7$$

$$A_0 = A \quad \sim 3' \text{ in}$$

$$A_{k+1} = \underbrace{Q_k^T}_{\cancel{\text{in}}} A_k Q_k$$

in \mathcal{N}

$$\sim \text{in } C_{ijk} \quad Q_k \cdot / \circ$$

~~$$A_k \rightarrow R \cdot \omega$$~~

$$\begin{pmatrix} \cancel{*} \\ 0 & 0 & \dots & 0 & \lambda \end{pmatrix}$$

$$\rightarrow \sqrt{3} \cdot \sim R$$

$$\left(\text{in } C_{ijk} \text{, } V_0 = \ell_m \right) \quad \underbrace{\quad}_{\text{in } \mathcal{S} \text{ in}}$$

$$Q_k = \begin{pmatrix} \cancel{*} & | & v_k \\ \sim & \text{in } C_{ijk} & \end{pmatrix} \cdot 3 \cdot \frac{w_k^* (A_k - \lambda_k I)}{v_k = w_k / \|w_k\|} = \cancel{\ell_m} \cdot 1 \cdot 2$$

$$A_{k+1} = Q_k^T A_k Q_k \cdot 4$$

$$(A_k - \lambda_k I) = \underbrace{Q_k R_k}_{\mathcal{C}} \quad \checkmark$$

$$Q_k R_k : (A_k - \lambda_k I)^{-1} = I$$

$$Q_k^* = R_k (A_k - \lambda_k I)^{-1}$$

$$\underbrace{e_m^* Q_k^*}_{= \underbrace{e_m^* R_k}_{\mathcal{C}}} (A_k - \lambda_k I)^{-1} =$$

$$\underbrace{r_0 \cdot e_m^*}_{(A_k - \lambda_k I)^{-1}} (A_k - \lambda_k I)^{-1} = \underbrace{\omega_k}_{\mathcal{C}} = v_k$$

$$R_k = \begin{pmatrix} i & * & i \\ j & i & \\ & & r_0 \end{pmatrix}$$

$$A_{k+1} = Q_k^T A_k Q_k =$$

$$Q_k^T (A_k - \mu I + \mu I) Q_k =$$

$$Q_k^T (A_k - \mu_k I) Q_k + Q_k^T \mu_k Q_k =$$

$$R_k Q_k + \mu_k I$$

Algorithm

$$QR \quad \text{find } R \quad \text{and} \quad K \in \mathbb{R}^{n \times n}$$

$$A_k - \mu_k I = Q_k R_k$$

$$A_{k+1} = R_k Q_k + M_k I \quad \text{and} \quad -2$$

$$\underbrace{\begin{pmatrix} * \\ \dots \\ 0 & 0 & v_k \end{pmatrix}}_{\text{rank } k} \leftarrow A_{k+1} \quad S'k$$

$$\gamma \left| \vec{G}_j \right| \left| \vec{w}_j \right| \quad \} \rightarrow \quad \text{Jacobi}$$

\vec{w}_j

$$(W_{n+1} (A - \mu I) = v_n \leftarrow \underbrace{\dots}_{v_0} \quad A^{\mu} v_0$$

$$v_{n+1} = \frac{w_{n+1}}{\|w_{n+1}\|} \quad w_{n+1}$$

$$w_n (A_n - \mu_n I) = e_m$$

$$A_n - \mu_n I = Q_n R_n \Rightarrow A_{n+1} = Q_n G + K_n I$$

$$A_n \rightarrow \begin{pmatrix} * & * \\ * & * \\ \hline 0 & 0 \end{pmatrix}$$

i.e. $\sum \mu_i = 0$; ($\lambda_1, \lambda_2, \dots, \lambda_n$)

$$\boxed{A_k = Q_k R_k}, A_0 = A.$$

$$A_{k+1} = R_k Q_k$$

$$(A - \mu I) = QR$$

$$Q = (A - \mu I) R^{-1}$$

$$(A - \mu I)^* = R^* Q^*$$

$$(R^*)^{-1} (A - \mu I)^* = Q^*$$

$$(A - \mu I) = Q R$$

$$I = Q R (A - \mu I)^{-1}$$

$$Q^+ = R(A - uI)^{-1}$$

$$\lim_{t \rightarrow \infty} e^{At} = \lim_{t \rightarrow \infty} R_j (A - \mu_j I)^{-1} =$$

$$e_m^* \cdot f(A - \mu I)^{-1} = f \cdot w_k$$

$$R = \left(\begin{array}{c} \text{triangle} \\ \text{triangle} \end{array} \right)$$

11

$$f > 0$$

$\lambda_{\text{CC}} \approx 1.05 \int A \text{ d}A$

value $\lambda_{\text{CC}} \approx 36$

$\lambda_1 > \dots > |\lambda_n| > 0$

own A_k be $\log f_{k+1}$ sc

number f_{k+1} part of $\log f_{k+1}$

- off own $\log f_{k+1}$

$A_k = Q_k R_k$, $A_{k+1} = R_k Q_k$

$A_k = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \begin{pmatrix} 1 & 3 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} 0 & 3 \\ 1 & 1 \end{pmatrix}$ (row 13)

$$A_K = Q_K R_K$$

∴ 2NIS

$$A_{K+1} = R_K Q_K = Q_K \underbrace{Q_K^T R_K}_{R_K} Q_K =$$

$$Q_K^T A_d Q_K = Q_K^T Q_{K-1}^T - Q_0 \underbrace{A_{Q_0 \dots Q_K}}_{U_{K+1}}$$

$$A_K = U_K^T A U_K$$

$$A^K = \underbrace{Q_0 R_0 \dots Q_0 R_0}_K = Q_0 A_1^{K-1} R_0 =$$

$$Q_0 Q_1 A_2^{k-2} R_1 R_0 = \dots = \underbrace{Q_0 \dots Q_{K-1} R_{K-1} \dots R_0}_\infty$$

$$= U_K S_K \Rightarrow U_K = A^K \underbrace{\varepsilon_K^{-1}}_{\varepsilon_K} \Leftrightarrow$$

$$A_k = S_k A^{-k} \cdot A A^k S_k^{-1} = \underbrace{S_k A S_k^{-1}}$$

$$A = X D X^{-1} \Leftrightarrow \text{rangsatz } A, \text{ v.l.o.s f/c } D$$

$$D = \begin{pmatrix} \lambda_1 & & 0 \\ & \ddots & \\ 0 & & \lambda_n \end{pmatrix}$$

$$\boxed{A_k = S_k X D X^{-1} S_k^{-1}}$$

: Bruhat decomposition für \mathfrak{so}_7

$$T \quad \mathfrak{so}_7 \quad \mathbb{R}^7 \rightarrow \mathbb{C}^7 \quad G$$

$$T = L \cdot P \cdot R \quad \rightarrow \quad \text{wegen } L \text{ ok} \quad$$

wegen R , kann man sagen L ok
 $\mathfrak{so}_7 \cap \mathfrak{p}$ ist \mathbb{R}^7 , $\mathbb{R}^7 \cap \mathfrak{n}^- = \mathfrak{p}$, $\mathfrak{n}^- \cap \mathfrak{p}$

$$X^{-1} = L P R$$

etc?

$$A_K = S_K \underbrace{R^{-1} P^{-1} (L^{-1} D L)}_{\text{wavy line}} P R S_K^{-1}$$

$$B_K = P^{-1} D_K \underbrace{L^{-1} \underbrace{D L}_{\text{DL}} D^{-1} P}_{\text{wavy line}} =$$

$$W_K = \underbrace{P^{-1} D^K P R S_K^{-1}}_{\text{wavy line}} \Rightarrow$$

$$A_K = W_K^{-1} B_K W_K$$

$$\begin{aligned} U_K S_K &= A^k = \\ X D^k X^{-1} & \end{aligned}$$

$$W_K = P^{-1} D^K P R S_K^{-1} =$$

$$\begin{aligned} P^{-1} (D^k L^{-1} D^{-1}) \underbrace{D^k X^{-1} S_K^{-1}}_{X^{-1} S_K^{-1}} &= \\ X D^k X^{-1} & \\ X^{-1} S_K^{-1} &= D^{-k} X^{-1} S_K^{-1} \end{aligned}$$

$$P^{-1} (D^k L^{-1} D^{-1}) X^{-1} U_K =$$

$\mathcal{A}' \cup \mathcal{S}_C \supseteq \mathcal{P}' \cap C_{\mathcal{V}}$ \cap \mathcal{D} $\supseteq \mathcal{S}_C$

$$B = \begin{pmatrix} \lambda_1 & \dots & \lambda_n \end{pmatrix}$$

$$\phi^{-1}(a_{ij}) D = \left(\star \left(\frac{\lambda_i}{\lambda_j} \right) a_{ij} \right)$$

$$\text{if } \left| \frac{\lambda_i}{\lambda_j} \right| < 1, \text{ then } \text{converges}$$

$$n \rightarrow \infty \text{ or } |c_i| > |c_j| \quad i > j$$



$$\underbrace{P^{-1} D P}_{D_{\pi}} = \begin{pmatrix} \pi^{(1)} & & \\ & \ddots & \\ & & \pi^{(n)} \end{pmatrix} \quad P = P_{\pi}$$

$$A_K = \omega_K^{-1} B_K \omega_K =$$

$$\omega_K^{-1} D_{\bar{\pi}} \omega_K + \omega_K^{-1} (B_K - D_{\bar{\pi}}) \nu_K$$

$\nearrow P$ $\searrow 0$

reform, each
stage

A_K be possess s_C

mean $\delta_{\bar{\pi}}$ $D_{\bar{\pi}} - \delta$ own

-0.5 own $\mu_0 \delta_{\bar{\pi}, d}$

Bruchat \rightarrow $\gamma_1 \gamma_2 \dots \gamma_n \gamma_1$

$$T := \begin{pmatrix} 0 & \dots & a & \dots \end{pmatrix} \quad a \neq 0 \\ \Rightarrow \exists R \\ \text{...} \\ \approx \text{...}$$

$$\overline{TR} = \begin{pmatrix} 0 & \dots & 1 & 0 & \dots \end{pmatrix} \Rightarrow L \\ \text{...} \\ \approx \text{...}$$

$$L \overline{TR} = \begin{pmatrix} 0 & \dots & i & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \end{pmatrix} \Rightarrow P$$

$$L \overline{TR} P = \begin{pmatrix} 0 & 0 & \dots & 0 \\ 0 & \dots & \dots & \dots \\ 0 & \dots & \dots & \dots \\ 0 & \dots & \dots & \dots \end{pmatrix} \quad T_1$$

L, P, R $\in \mathbb{M}_n(\mathbb{C})$

$$T_1 = \sum_i P_i D_i \\ L \overline{TR} P = \sum_i \tilde{P}_i \tilde{R}_i$$

$$\tilde{R}_1 \quad \text{sign } P$$

$$\begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & \text{triangle} \\ 0 & 0 \\ 0 & 0 \end{pmatrix} \cdot P = P \cdot R_2$$

sign and R_2

row echelon form

\rightarrow always a col/row

$$A = LPU$$

L, N/A's zeros, U zero

row echelon P-1 sign and sign

sign of P-1 sign of P-1

$\Rightarrow B \rightarrow \text{Graf } |'n'n A \leq \sqrt{\delta})$

$A \leq \lambda Q/nm \leq \sqrt{\delta}$

$\neg \exists n \in \mathbb{N} \Rightarrow \forall \delta \exists N \in \mathbb{N} \quad B$
'ז' סר ג' מילס פ'ג' ג'
'א' נ' ג' א' צ'ס'

$\wedge \exists j \in \mathbb{N} \quad \forall k \in \mathbb{N} \quad (\exists i \in \mathbb{N} \quad \forall$

$\forall j \in \mathbb{N} \quad \forall k \in \mathbb{N} \quad \exists i \in \mathbb{N} \quad \forall$
 $\forall i \in \mathbb{N} \quad \forall j \in \mathbb{N} \quad \exists k \in \mathbb{N} \quad \forall$

$V = \text{IFR} \rightarrow \text{def} \quad \text{def} \quad \text{def}$

$AV = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$

LAU \rightarrow L, U P' src

$$LAU = \begin{pmatrix} 0 & \dots & 1 & 0 & \dots & 0 \\ 1 & 1 & \vdots & 0 & \dots & 1 \\ 1 & 1 & \vdots & 1 & \dots & 1 \end{pmatrix}$$

LAUP \rightarrow L, U P' src

$$LAUP = \begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & & & \\ \vdots & & A_1 & \\ 0 & & & \end{pmatrix}$$

x' 3 > 12 / 12

$$A_i = L_i, P_i, U_i$$

$$\tilde{L}_i = I \oplus L_i \quad \text{JND}$$

$$\begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & & & \\ \vdots & & \tilde{L}_i & \\ 0 & & & \end{pmatrix} \Rightarrow LAUP = \tilde{L}_i, \tilde{P}_i, \tilde{U}_i \Rightarrow$$
$$LAC = \overline{\tilde{L}_i, \tilde{P}_i, \tilde{U}_i}$$

- $\sim \tilde{U}_1 P$ $\text{libBn} \int$ reac $\xrightarrow{\text{rg}}$ G

$$\underbrace{\tilde{U}_1 \cdot P^{-1}}_{=} = P^T U^T \quad \Rightarrow \quad P(j) = 1$$

$\text{arg} \int v \text{ dist } P$ $\xrightarrow{\text{rg}}$

$$P(i) = i+1 \quad i < j \quad \therefore 1 - \delta_{ij}$$

$$P(j) = 1 \quad P(j) = P_j e^{-\cdot}$$

$$P(i) = i \quad i > j$$

$$\tilde{U}_1 \begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & \ddots & & \\ \vdots & & \ddots & 0 \\ 0 & 0 & \dots & 0 \end{pmatrix} \Rightarrow$$

$$\tilde{U}_1 \cdot P^{-1} \xrightarrow{\text{?}} \begin{pmatrix} 0 & \dots & 0 & | & 0 & \dots & 0 \\ 0 & \dots & 0 & | & 0 & \dots & 0 \\ \vdots & & \vdots & | & \vdots & & \vdots \\ 0 & \dots & 0 & | & 0 & \dots & 0 \end{pmatrix} \Rightarrow$$

$$P \cdot \tilde{U}_1 P^{-1} = \begin{pmatrix} X & 0 & Y \\ 0 & \ddots & 0 \\ 0 & 0 & Z \end{pmatrix} \in \mathbb{M}^{3^k, 3^k}$$

• $\sqrt{17} \approx 4.1231$

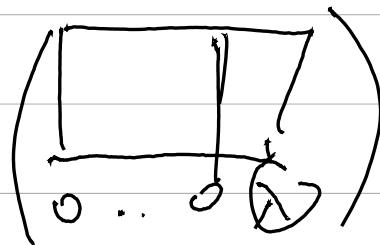
$A_k R$ \rightarrow $\lambda' \sqrt{f_k}$

$$A_k - \mu_k I = Q_k R_k$$

$$A_{k+1} = R_k G_k + \mu_k I$$

$A_{k+1} - \mu_k I = Q_k$

$A_k \rightarrow$



$$\left(\begin{array}{c|c} B_k & w_k \\ \hline r_k & t_k \end{array} \right) \quad \|R_k\| \rightarrow 0 \quad \text{and} \quad \text{converges}$$

$$\begin{array}{c}
 Q_k \\
 R_k \\
 \left(\begin{array}{c|c} B_k - u_k & w_k \\ \hline r_k & \lambda_k - u_k \end{array} \right) = \left(\begin{array}{c|c} P_k & u_k \\ \hline v_k & \alpha_k \end{array} \right) \left(\begin{array}{c|c} S_k & t_k \\ \hline 0 & g_k \end{array} \right) \quad (1)
 \end{array}$$

$$\left(\begin{array}{c|c} B_{k+1} - u_k & w_{k+1} \\ \hline r_{k+1} & \lambda_{k+1} - u_k \end{array} \right) = \left(\begin{array}{c|c} S_k & t_k \\ \hline 0 & g_k \end{array} \right) \left(\begin{array}{c|c} P_k & u_k \\ \hline v_k & b_k \end{array} \right) \quad Q_k$$

$$v_k = v_k \cdot s_k \quad v_{k+1} = s_k v_k$$

↓

$$v_k = v_k \cdot s_k^{-1}$$

$$\|v_{k+1}\| \leq |s_k| \cdot \|v_k\| \cdot \|v_k\|$$

↓

$$\|v_k\| \leq \underbrace{\|s_k^{-1}\|}_{r_k} \cdot \|v_k\|$$

$$\left(\begin{array}{c|c} S_u & t_u \\ \hline 0 & S_u \end{array} \right) = \left(\begin{array}{c|c} P^* & V_k^* \\ \hline U_k^* & I_k \end{array} \right) \left(\begin{array}{c|c} R_u - e_u & C_k \\ \hline V_k & I_k \end{array} \right)$$

$$f_u = u_u^* w_k + \bar{\varphi}_u (\lambda_k - e_u)$$

$$|f_u| \leq |u_u \cdot w_k| + \bar{\varphi}_u (\underbrace{\lambda_u - e_u}_{\sigma_k})$$

$\{ \text{C. } \mu_u = \lambda_k \rightarrow \text{nn} \}$

$$|f_u| \leq \|u_u\| \cdot \|w_k\| = \|V_k\| \cdot \|U_k\| \leq$$

$$\underbrace{\sigma_k \cdot \|V_k\| \cdot \|U_k\|}$$

$$\|V_{k+1}\| \leq \underbrace{\sigma_k^2}_{\sigma_k} \|W_k\| \|V_k\|^2$$

A_n für $\lambda \geq 13\pi/2$

$$\|w_n\| \leq \|A_n\| = \|A\|$$

$$A_n = \left(\begin{array}{c|c} B_n & w_n \\ \hline v_n & * \end{array} \right)$$

$$w_n$$

$$A_{n+1} = \underline{\underline{Q_n^T A_n B_n}}$$

$$\|A_n\| \geq \underline{\underline{\|w_n\|}} \geq \|w_n\| + \epsilon$$

$$(A^* A = A A^*) \text{ ist } \text{regulär} \text{ in } \mathbb{C}^n \text{ da } \rightarrow 0$$

$|z|$ A_n $\rightarrow 0$ in \mathbb{C}

$$\|w_n\| = \|v_n\|$$

$$A_k^* A_{k*} = \left(\begin{array}{c|c} & v_k^* \\ \omega_n^* & x \end{array} \right) \left(\begin{array}{c|c} v_k & \omega_n \\ r_k & x \end{array} \right) =$$

$$\left(\begin{array}{c|c} & 1 \\ & 1 \\ \hline & \|v_k\|^2 + x \end{array} \right)$$

$$A_n^* A_n = \left(\begin{array}{c|c} & \omega_n \\ r_k & x \end{array} \right) \left(\begin{array}{c|c} \omega_n \\ \hline \omega_n^* & x \end{array} \right) =$$

$$\left(\begin{array}{c|c} & 1 \\ & 1 \\ \hline & \|v_k\|^2 + x^2 \end{array} \right) \Rightarrow \|\omega_n\| = \|v_k\|$$

$$\|v_{k+1}\| \leq \begin{cases} r_n^2 \|v_k\|^2 \|A\| & \text{if } \\ \underline{r}_n^2 \|v_k\|^3 & \text{else} \end{cases}$$

? 2/70 ✓ A 5f
~5/11 4

? r_k $\approx c$

$$r = \|S_k^{-1}\|$$

- e $\gamma_{ij}(1) \sim$

$$P_k \cdot S_k = B_k - \mu_k$$

$$\underbrace{S_k^{-1}}_{=} = \underbrace{(B_k - \mu_k)^{-1}}_{=} \cdot \underbrace{P_k}_{=}$$

$$r_k = \|S_k^{-1}\| \leq \underbrace{\|(B_k - \mu_k)^{-1}\|}_{= \overbrace{\text{sep}(\mu_k, B_k)}} =$$

A_k

$$\left(\begin{array}{c|c} B_k & w_k \\ \hline r_k & t_k \end{array} \right)$$

\downarrow

$$\left(\begin{array}{c|c} B & w_k \\ \hline 0 & \lambda \end{array} \right)$$

$$P_n = (B_n - \mu_n) S_n^{-1}$$

ϕ

$$\mu_n \rightarrow \lambda$$

$\lambda \nearrow \sigma$

$A_n \in C_{\sigma}$

$$A_1 \in \mathbb{C}^{n \times n}$$

$$\|A_1\| \leq \|A\|$$



$$\sigma(B_\alpha) \subseteq \sigma(A_\alpha)$$

λ

$$\tilde{\lambda}_k \rightarrow \lambda$$

$$m_k$$

$$\delta_{n,q} = \underbrace{\theta_n^*}_{\text{---}} \delta_n \theta_n$$

$$W_n(1 - \mu I) = W_n$$

$$\underbrace{|\lambda_1 - \mu|}_{<} < |\lambda_2 - \mu|$$

$$A = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

$$\left(\begin{array}{c|c} x & x \\ \hline x & x \end{array} \right)$$

$\leftarrow \tau^{\rightarrow} \circ \tau^{\rightarrow 3} \circ \tau^{\rightarrow} \neq 1$

$A = L P U$ \Rightarrow L and U are closed
 $\Rightarrow P$ is a σ -algebra - U
 $\underline{\text{and } P}$

$\cup E_i \subseteq E_i \Rightarrow P$ is a σ -algebra \cup

$E_i := \langle e_1, \dots, e_i \rangle$, $i \in \mathbb{N}$

$L F_i \subseteq F_i \Rightarrow L$ is a σ -algebra \cup

$F_i := \langle e_n, \dots, e_{n-i+1} \rangle$, $i \in \mathbb{N}$

$L_1 P_1 U_1 = L_2 P_2 U_2 \quad -\text{e} \quad \wedge' \cup$

S'_c

$L_1 P_1 U_1 E_i = L_2 P_2 U_2 E_i = L_2 P_2 E_i$
 \Downarrow

$L_1 P_1 E_i$

$$L, \underbrace{(P_1 E_i \wedge F_j)}_{\cdot} =$$

$$L, P_1 E_i \wedge L, F_j = L, P_1 E_i \wedge F_j$$

$$= L_2 P_2 E_i \wedge F_0 = L_2 \underbrace{(P_2 E_i \wedge F_j)}_{\cdot}$$

3. Nächste, i,j 520: insgesamt

520

$$\underbrace{P_1 E_i \wedge F_j}_{\cdot}$$

$$P_2 E_i \wedge F_j \quad \text{für } 3 \leq i \leq n$$

$$P_1 E_i = \{ e_{\pi, (1)}, \dots, e_{\pi, (i)} \}$$

$$\dim(P_1 E_i \wedge F_j) = \# \pi(\{1, \dots, i\}) \cap \{n-i+1, \dots, n\}$$

$i, j \in \mathbb{N}$ $\pi_1, \pi_2 \in S_n$ $\text{per } \underline{\text{def}}$

$$|\pi_1(\{1, \dots, i\} \cap \{j, \dots, n\})| =$$

$$(\pi_2(\{1, \dots, i\} \cap \{j, \dots, n\})) = a_{ij}$$

$$\pi_1 = \pi_2 \quad \text{sc}$$

\Rightarrow \sim Cnf \wedge \forall $(\forall x)$ \rightarrow \forall \forall

$\forall y \forall x$ $\forall y \forall x$ \vdash A

$$a_{ij} \in \dim(A E_i \cap F_j)$$

$: 2 \times 2 \quad A \quad \underline{\text{is def}}$

$$\underline{A E_1 = F_1} \quad \Rightarrow A = \begin{pmatrix} 0 & x \\ * & * \end{pmatrix}$$

$\pi(1) = 2$ \vdash $\forall y \forall x$ \sim ρ/c

$$\pi(2) = 1$$

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

: QR $\rightarrow \mathbb{R}^+, \{f_k\}$

$$A_K = \underbrace{Q_K R_K}_{L} + \mu_K I$$

$$A_{K+1} = \underbrace{R_K Q_K}_{L} + \mu_K I$$

$$\begin{matrix} \text{r/c} & \sum_j \cdot j & \rightarrow 1 & \rightarrow \sum_j j^2 & n^3 \\ \text{r/c} & \sum_j j^2 & \rightarrow 1 & \rightarrow \sum_j j^3 & n^4 \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j^3 & \rightarrow 0 & \rightarrow \sum_j j^4 & n^5 \\ & & \downarrow & & \\ & & : n^3 - \sum j^3 & & \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j^4 & \rightarrow 13 & \text{diff. 1} \\ \text{r/c} & \sum_j j^5 & \rightarrow 31 & \text{diff. 2} \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j^6 & \rightarrow 13 & \text{diff. 2} \\ & & \downarrow & \\ & & : \text{Ansatz} & \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j^6 & \rightarrow 13 & \text{diff. 2} \\ \text{r/c} & \sum_j j^7 & \rightarrow 40 & \text{Ansatz} \\ & \sum_j j^8 & \rightarrow 70 & \\ & \sum_j j^9 & \rightarrow 103 & \end{matrix}$$

$$H = \underbrace{\begin{pmatrix} * & * & * \\ * & * & * \\ 0 & * & * \end{pmatrix}}_{\text{Hess. eckig}}$$

λ^1, λ^2

γ_1, γ_2

$$HE_i \subseteq E_{i+1}$$

($\forall i \in \mathbb{N} : E_i$) ist Ld

Wesentlich \cup γ_1, γ_2

$\cup H, H \subseteq \underline{H}$ gg

$$(H \cup) (E_i) = H (E_i) = HE_i \subseteq E_{i+1}$$

$$(\cup A) (E_i) \subseteq \cup (E_{i+1}) = \underline{E}_{i+1}$$

$$A_k = Q_k R_k + \underbrace{\mu_k I}_{S_k} \Rightarrow Q_k \in \underline{H}$$

$$A_{k+1} = R_k Q_k + \mu_k I \leftarrow \cancel{+ S_k}$$

\mathbb{R}^n 中の \mathcal{G}_R の上に \mathcal{F}_C を定義する。

Q_1, \dots, Q_m

? (1) \mathbb{R}^n 上で \mathcal{F}_C を

$A = \bigcup_{k=1}^m H_k$, $H_i \in \underline{\mathcal{H}}$

$$A = \left(\begin{array}{c|c} a & x \\ \hline y & A_1 \end{array} \right) \rightsquigarrow y \mapsto \begin{pmatrix} b \\ 0 \\ \vdots \\ 0 \end{pmatrix}$$

$$\left(\begin{array}{c|c} a' & \rightsquigarrow \\ \hline b & A_1 \\ \hline 0 & \end{array} \right)$$

$$b = \|y\|$$

: Q R planes and 3D 8/6

13nd x 16/11 planes

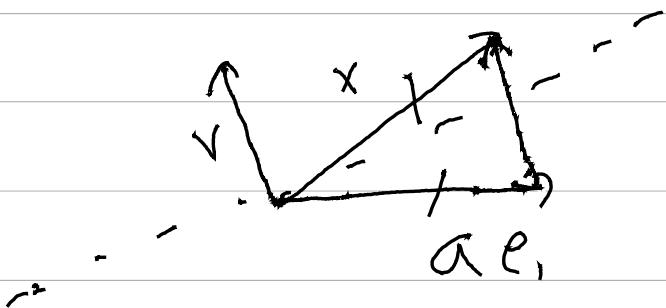
Q } ⊥ Q r' C J / C = 3' C v

$$Q x = a e_1$$

$$|a| = \|x\|, \quad \text{for } 13^{\text{th}}$$

13th → CSQ Q 13th -||r||

. 8/12



orthogonal on 3D planes 8/12 5/6

$$\sqrt{x} = x - a e_1 - \delta \text{ j j o w}$$

(x, -5y, a for 13th 8/12)

$\sqrt{12/100}/(\rightarrow \sqrt{3})$ für $\approx 3'7\text{Cm}$

'2' $\sqrt{2/100} \vee |1'| > \delta$

$$\frac{\mathbf{V} \cdot \mathbf{V}^*}{\|\mathbf{V}\|^2}$$

$\mathbf{V}^*, u=0 \Rightarrow u \perp v$

$$\boxed{(\mathbf{V} \cdot \mathbf{V}^*)}(u) = 0$$

'3' für $u \perp v \quad \text{sic}$

$$I - \frac{2\mathbf{V} \cdot \mathbf{V}^*}{\|\mathbf{V}\|^2}$$

in 10 $\mathbf{V} = \mathbf{X} - \alpha \mathbf{e}_1$ in 10

$$|\alpha| (= \|\mathbf{x}\|)$$

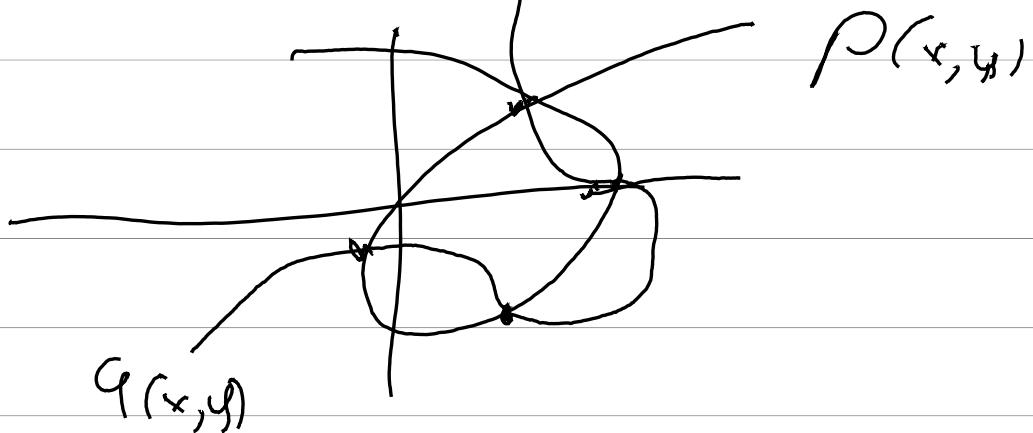
Numerical methods for solving linear systems

$$P_1(x) = 0, \dots, P_n(x) = 0$$

linear system of equations P_i :

$$\begin{array}{l} xy = 0 \Rightarrow \\ \quad x = 0 \text{ or} \\ \quad y = 0 \\ \hline x = 0 \end{array}$$

$$P(x, y) = 0 = Q(x, y)$$



$$P_1, \dots, P_\alpha$$

$$P_1(\bar{a}) = \dots = P_\alpha(\bar{a})$$

$$q_1, \dots, q_n \quad \text{numbers} \quad p' \quad \text{etc}$$

\rightsquigarrow

$$\underbrace{q_1 P_1 + \dots + q_n P_n}_{= 1}$$

$\Rightarrow \zeta : \text{Complex plane} \rightarrow \text{Unit circle}$

numbers like ζ^k ($k \in \mathbb{Z}$)

$(\zeta^n, \zeta^{n+1}, \dots, \zeta^{n+k})$

length of ζ is n . ζ^k has length n . $\zeta^k = q_i \cdot \zeta$

- $\gamma' \cap \{f_1, f_2, \dots, f_r\}$: \mathbb{C}^*

$$P(x) = X^n + \sum_{i < n} a_i x^i$$

$S_r = \{z \in \mathbb{C} \mid |z| = r\}$

знач / 'r_r P - фк \cong $\frac{1}{r}$

0 > r > d' > S_r \Rightarrow $\lim_{r \rightarrow 0}$

$$P_t(x) = X^n + (1-t) \sum_{i < n} a_i x^i$$

$$P_0 = P \quad P_1 = X^n$$

$P_t(a) \neq 0$ для $a \in S_r$, $t \in [0, 1]$

$f \approx g$ \Leftrightarrow $P_t : S_r \rightarrow \mathbb{C} \setminus \{0\}$

$e^t \circ f, g : S_r \rightarrow \mathbb{C} \setminus \{0\}$

$$H : S_r \times [0, 1] \rightarrow \mathbb{C} \setminus \{0\}$$

$H(a, 0) = f(a), \quad H(a, 1) = g(a)$

$f \sim g \Leftrightarrow \exists t : f(a) = e^{-t} g(a) \quad \forall a \in S_r$

$$P \sim P_0$$

$\sim \mathcal{N}'_{IC, \gamma}$

$$P_0(x) = \sum_{n \in \mathbb{N}} f_n P_{\text{def}} \geq P_{\text{def}} \cdot n^{\alpha}$$

$$H(a, t) = P((1-t) \cdot a) \quad \xrightarrow{\quad} \underline{P \circ a}$$

$$\gamma' \partial / \partial \gamma \quad \cancel{z \mapsto z^n - 1} \quad \cup \cup \beta \sim$$

$$\rightarrow \gamma \circ \gamma' \circ \delta$$

initial value problem \rightarrow ODE/CD

$$P_1(\tilde{x}) = \dots = P_n(\tilde{x}) = 0 \quad \text{and} \quad q_1(\tilde{x}) = \dots = q_n(\tilde{x}) = 0$$

initial condition or initial value problem

$$\text{, initial value problem} \quad q_1(\tilde{x}) = \dots = q_n(\tilde{x}) = 0$$

$$\underline{h}(\tilde{x}, t)$$

$$h(\tilde{x}, 1) = P(\tilde{x}) \quad h(\tilde{x}, 0) = \underline{q}(\tilde{x}) \quad \rightarrow \text{LCS}$$

$$\text{Initial value problem, } q(\tilde{x}_0) = 0 \quad \text{at } t=0$$

$$\tilde{x}(0) = \tilde{x}_0, \quad h(\tilde{x}(t), t) = 0 \quad \rightarrow \quad \underline{\tilde{x}(t)}$$

$$\text{at } t=0 \quad \rightarrow \quad \tilde{x}(1) \quad \text{at } t=1$$

$$P, q: \mathbb{R}^n \rightarrow \mathbb{R}^n \quad P(\tilde{x}) =$$

$$P_1(x, y) = \underbrace{x^2 + 4y^2 - 4}_{{}'/(r^2/3)} = 0$$

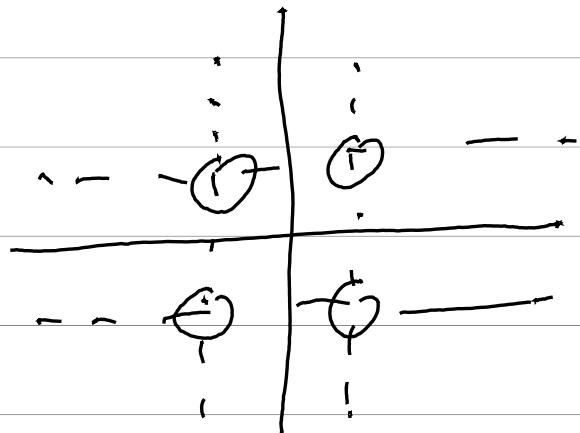
$$P_2(x, y) = 2y^2 - x = 0$$

$$q_1(x, y) = \underbrace{x^2 - 1}, \quad q_2(x, y) = \underbrace{y^2 - 1}$$

$$h(x, y, t) = (1-t) \cdot \tilde{q}(x, y) + t \cdot \tilde{p}(x, y)$$

$$\underbrace{x^2 - 1}_{{}''} = 0$$

$$(x-1) \cdot (x+1)$$



$$P_1(x, y) = \underline{y} = 0$$

curve

$$P_2(x, y) = \underline{y - r(x)}$$

surface $r(x)$

$$r(x) = x^2 + 1$$

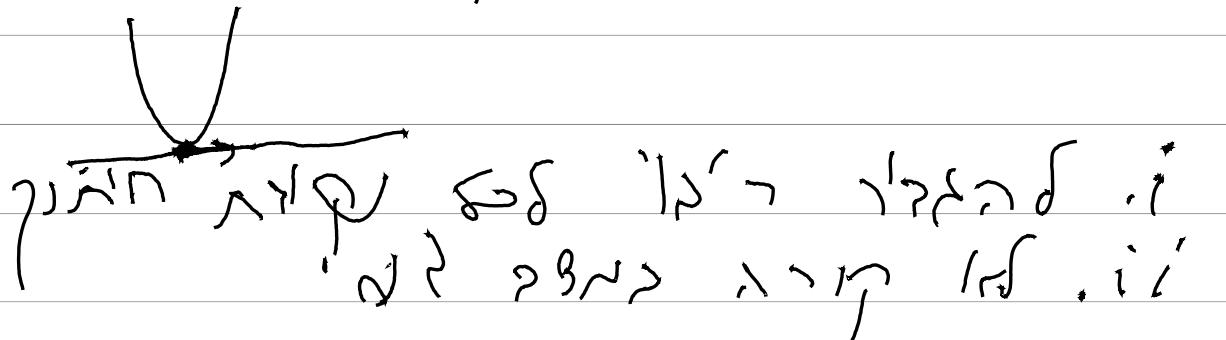
$f(x)$

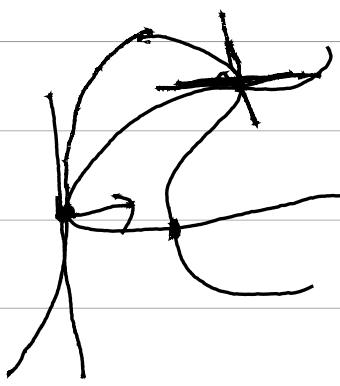
$$\mathbb{R} \rightarrow \mathbb{R} \rightarrow \text{Mild } f(x)$$

(-f) \rightarrow up side down

more mild curve \rightarrow $f(x)$

$$\text{more } f(x) = x^2$$





ל'ר'ן גלגולן מנגנון

ט'ג'לולן ס'ס' "הרכז"

$$\left\langle \frac{\partial P_2}{\partial x}, \frac{\partial P_2}{\partial y} \right\rangle, \quad \left\langle \frac{\partial P_1}{\partial x}, \frac{\partial P_1}{\partial y} \right\rangle$$

מונט טרינגדון מילר פ'ס'

$$\begin{pmatrix} \frac{\partial P_2}{\partial x} & \frac{\partial P_1}{\partial x} \\ \frac{\partial P_1}{\partial x} & \frac{\partial P_2}{\partial y} \end{pmatrix}$$

ט'ג'לולן ס'ס' מילר

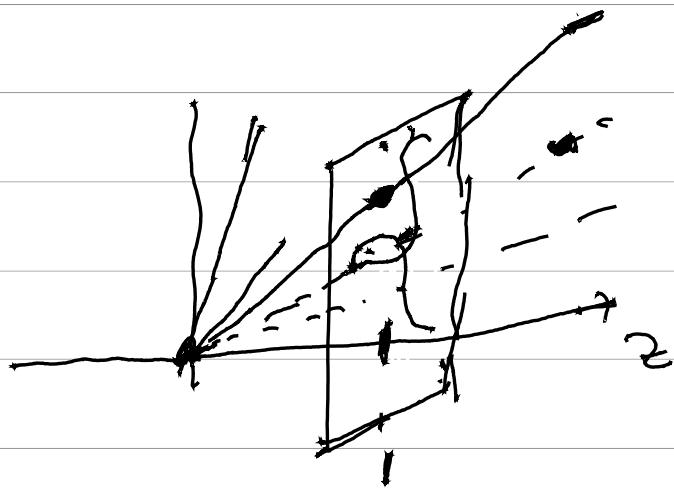
ט'ג'לולן ס'ס'

$$f(x) = 1 \quad \text{ל'}$$

$$y=0, \quad y=1$$

ט'ג'לולן ס'ס'

('אינטגרל נורמליזציה של פונקציית גausian) $\int_{-\infty}^{\infty} e^{-x^2/2} dx = \sqrt{\pi}$



$\gamma_{y=0}$ x y z/r^2 πr^2 $\approx \pi r^2 \cdot 1/c$

$\mathbb{R}^3 - \mathcal{P} \left\{ (x, y, z) \mid z = 1 \right\}$ $\approx 3/\pi \approx 3$

18 ρ_{FU} $\lambda^3/\rho V$ Σ $\approx \pi r^2 \dots$

ρ, ρ $\gamma \gamma$ $\rho \rho \rho \rho$ $\gamma \gamma \gamma \gamma$ $\rho \rho \rho$

$\mathbb{P}^n = \left\{ l \subseteq \mathbb{K}^{n+1} \mid \text{...} \right\}$ $\gamma \gamma \gamma \gamma \gamma \gamma$

\mathbb{P}^2 $\subseteq \mathbb{R}^3 - \mathcal{P}$ $\gamma \gamma \gamma \gamma \gamma \gamma$ $\gamma \gamma \gamma \gamma \gamma \gamma$

$P(x, y, z)$

$$\underbrace{x^2 + y^2 = 1}$$

$$x = \frac{x'}{z}, \quad y = \frac{y'}{z} \quad \Rightarrow$$

$$\frac{x'^2}{z^2} + \frac{y'^2}{z^2} = 1$$

$$P(x, y, z) =$$

$$\cancel{x^2 + y^2 = z^2}$$

$$\left| \begin{array}{l} P(x_0, \dots, x_n) \text{ ist} \\ \text{ ein } n\text{-dimensionaler } \int \text{ auf } \\ P = 0 \quad \text{sic} \\ \Rightarrow \exists x_0, \dots, x_n \in \\ \mathbb{R}^n \quad \rightarrow \end{array} \right.$$

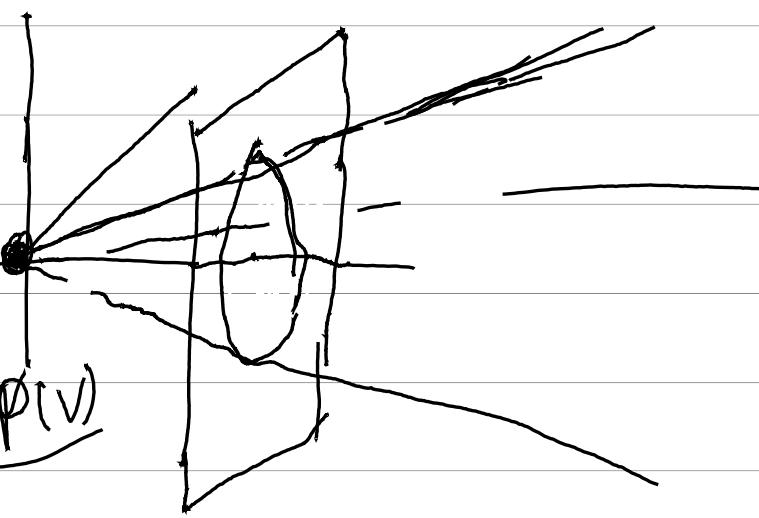
$$(1, 1, 1)$$

$$\underbrace{x'^2 + y'^2 = 0}_{(= z = 0)}$$

$$P(1, 1, 1) = 1$$

$$P(2, 2, 2) = 1$$

$$P(\lambda \cdot v) = \lambda^n P(v)$$



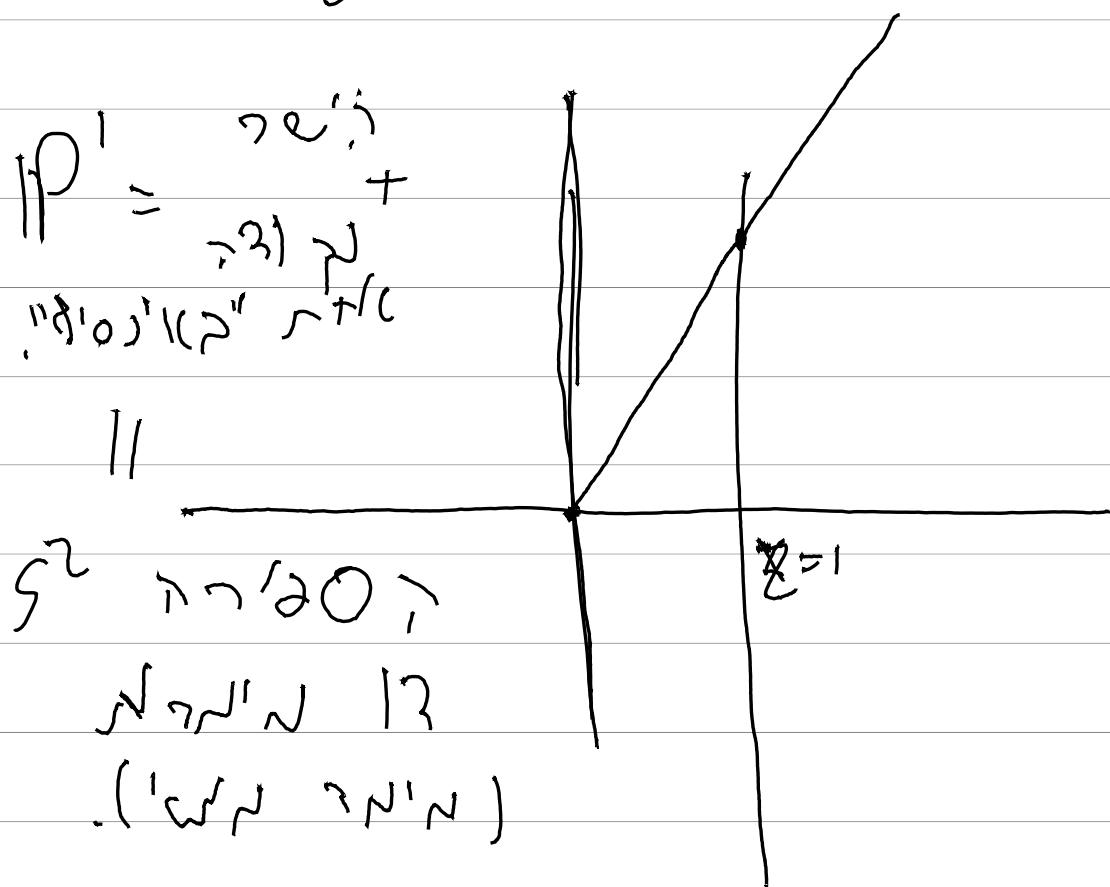
$$y = 0 \quad y = 1$$

$$y = \frac{g}{x}$$

$$y' = 0 \quad y' = 2 \quad \Rightarrow$$

$$z = 0$$

$$|P|^1 = \text{real part} + i \text{imaginary part}$$



ר' נייר ווּ כָּלְבָן : ISP Com

P_n(x₀, ..., x_n), P₁(x₀, ..., x_n) מילויים

x₀, ..., x_i מושג מילויים

מילוי מושג מילויים P_i-

הו גלויה מילויים מילויים

מונוטון (מילויים מילויים)

d₁, ..., d_n מילויים מילויים מילויים

המילויים מילויים מילויים מילויים

P_i

$\sqrt{f_0} \approx n$ $P_2, P_1 - 1$ $n=2$ ω/c

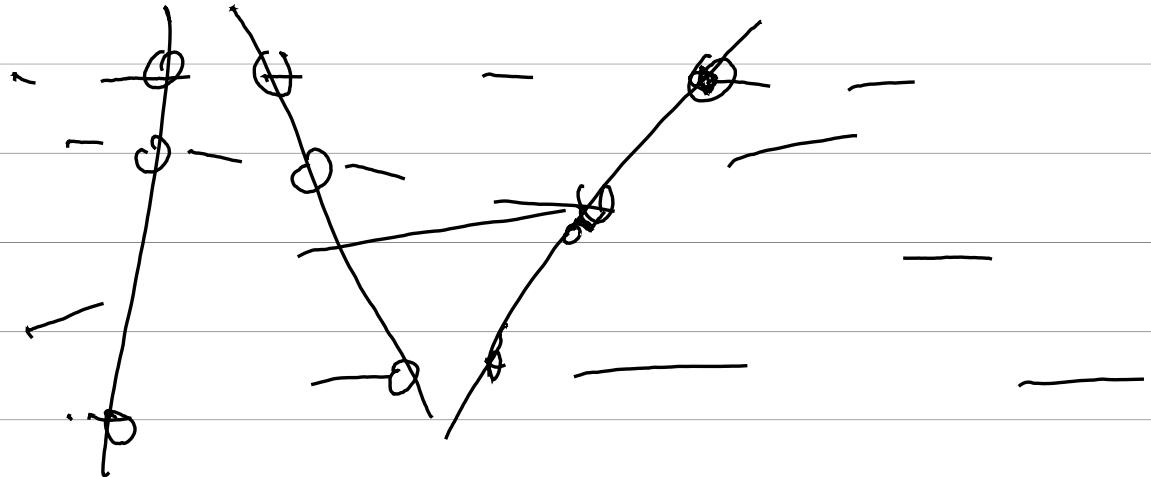
$\sim \gamma J \delta \omega / \hbar \omega_0$ $d_2 - 1$ \underline{d}_1 \hbar

$\mu U_{1,2,3} \sim \gamma^2 / \hbar \gamma \propto -\omega \gamma J J$

$\gamma^2 / \hbar \gamma \propto -1$ $f = 0$ ∇

$\gamma^2 / \hbar \gamma \propto f, g = 0$ $\propto \omega J_1 m_2 \propto$

$X \otimes Y \propto f \cdot g = 0$ $\propto \omega J_1 m_2 \propto -1$
 P_1



$$\underline{x^2 + 4y^2 - 4 = 0}$$

$$= \bar{P}(x, y)$$

$$\underline{2y^2 - x = 0}$$

$$\therefore$$

$$x^2 - 1 = 0$$

$$= \hat{q}(x, y)$$

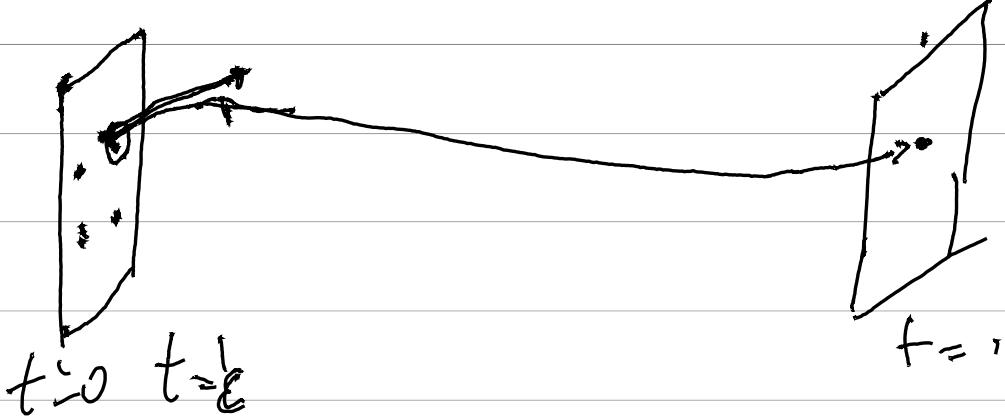
$$y^2 - 1 = 0$$

$$h(x, y, t) = (1-t)\bar{q} + t \cdot \bar{P}$$

$$y_0 - x_0 = 1$$

$$h(x_0, y_0, 0) = 0$$

$\text{arc: } \gamma_{\text{Natur}}$ $\gamma_{\text{Bsp/Ex}}$ Gesw



$h(x, y, t) \approx$

t לש $'g$ כ x, y ו $h \rightarrow g$ כ Δ

ו (x_0, y_0) לש Δ כ Δ

$$\left(\frac{\partial h}{\partial x} \cdot \frac{\partial h_1}{\partial y} - \frac{\partial h_2}{\partial x} \cdot \frac{\partial h}{\partial y} \right)$$

$\{0, 1\} \ni t - \int_{\text{לע}}^t \gamma^3 dt$

לש Δ כ Δ

הנ Δ כ Δ כ Δ

$$(1-t)(x^2 - 1) +$$

$$t(x^2 + uy^2 - 4) = 0$$

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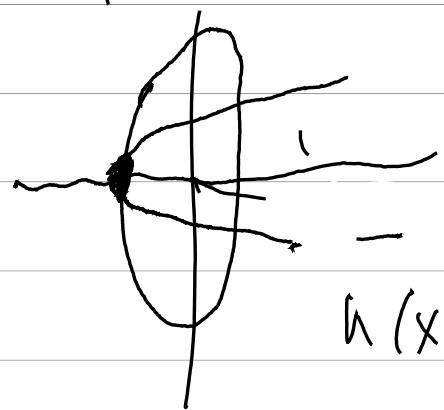
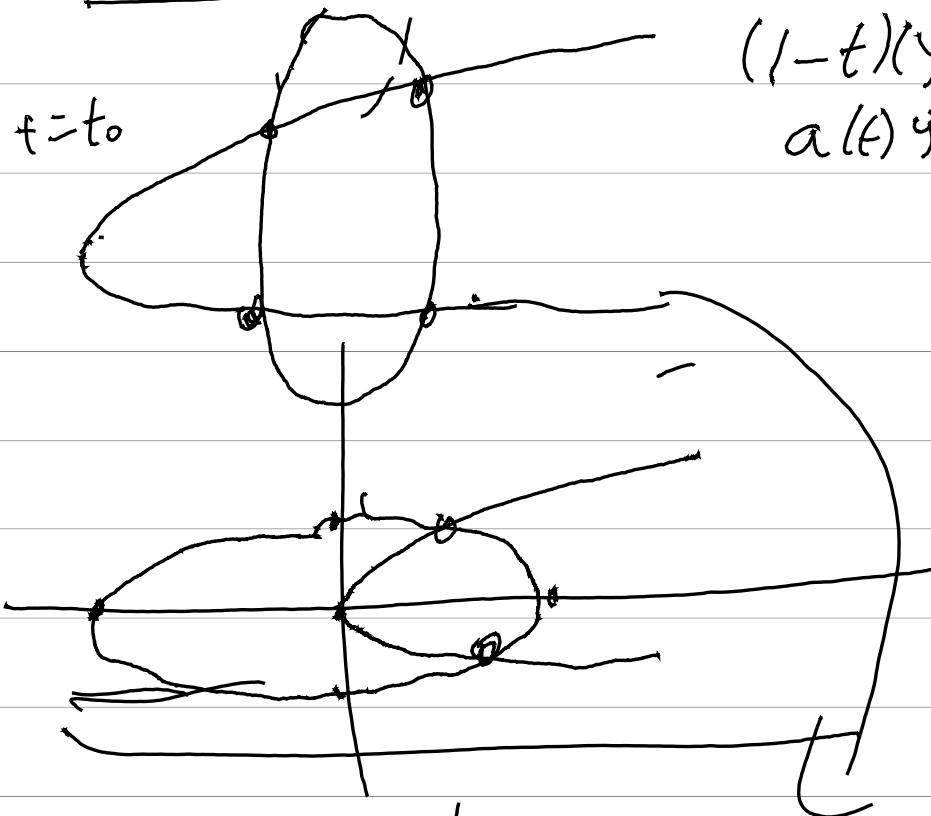
$$\underline{x^2 + uy^2 + t - 1 - ht = 0}$$

$$(1-t)(y^2 - 1) + t(2y^2 - x) =$$

$$a(t)y^2 + b(t) \cdot x = c(t)$$

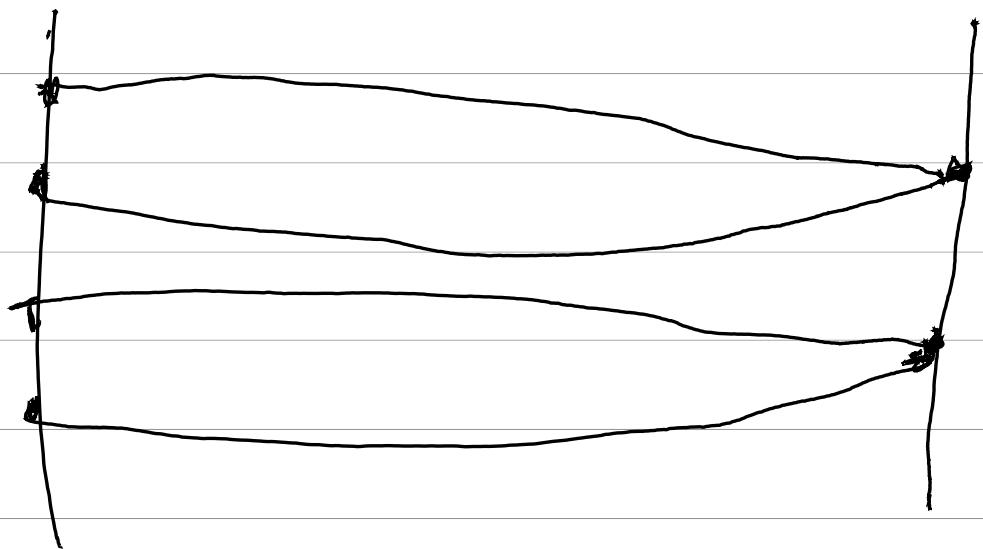
$$\underline{x^2 + uy^2 - 4 = 0}$$

$$2y^2 - x = 0$$



снабж , λ y^2
, λ x^2 ∂

$$u(x, y, t) = \underline{\lambda(1-t)\hat{g} + t \cdot \hat{p}}$$



$$t \in \{0,1\}$$

$$A : U \rightarrow V = K^n$$

↑ ↴ ↵

K^n

b

$V \in \text{Im}(A)$ \rightarrow $\exists p \in U$ $A(p) = b$

A_u w $b - b$ \rightarrow p b

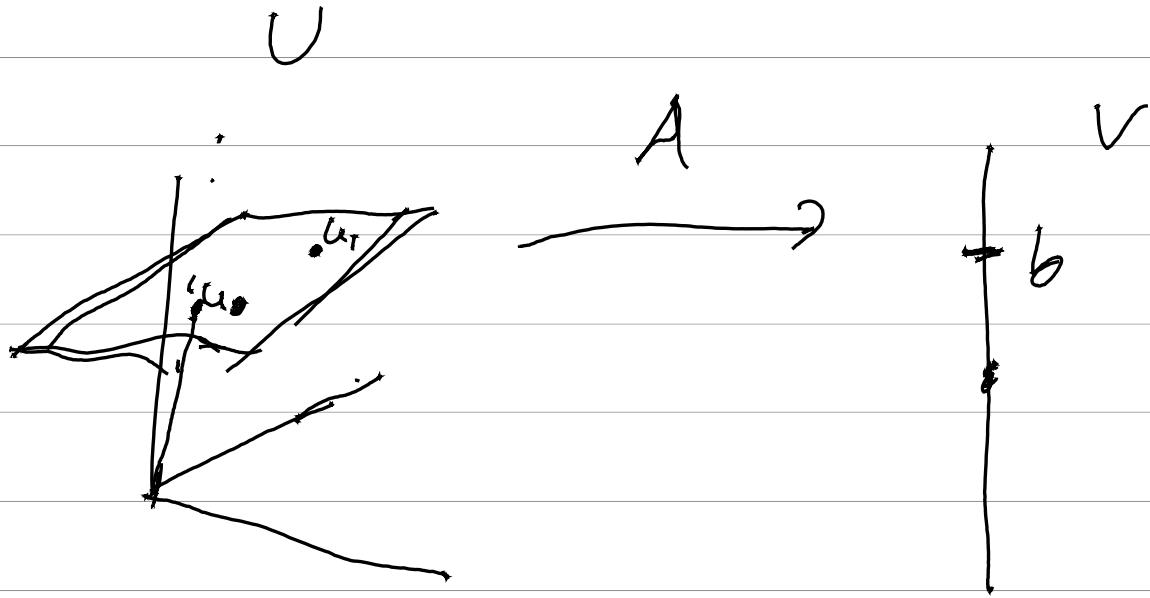
$A^* A_u = A^* b$

$\text{Im}(A)^\perp = \ker(A^*)$

$\text{Im}(A)^\perp = \ker(A^*)$

$A_u - b \perp \text{Im}(A) = \ker(A^*)^\perp$ \Rightarrow

$A^*(A_u - b) = 0$



$$U_0 \perp \ker(A)$$

$A : U \rightarrow V$
 $A^* : V^* \rightarrow U^*$

$\langle A^* v, w \rangle =$
 $\langle v, A w \rangle$

$$T x = b$$

$$\left\{ \begin{array}{l} T = L U \\ Ly = b \end{array} \right.$$

$$T = Q R$$

\rightarrow Separation of variables

Matrix solution R

$$Q y = b$$

$$Q^T = Q^{-1}$$

$$y = Q^T b$$

$$R x = y$$

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} y_1 \\ y_2 \end{pmatrix}$$

$$a x_1 + b x_2 = y_1$$

$$c x_2 = y_2 \Rightarrow x_2 = \underline{\frac{y_2}{c}}$$

Proof where we multiply by π

$$\cancel{IP} / \{ p\pi \mid p \in IP \} = V$$

$$\dim(V) = \deg(p)$$

$$T: V \rightarrow V \quad \underline{T(v) = t \cdot v}$$

$$\tilde{T}: P \rightarrow P \quad \tilde{\underline{T}}(v) = t \cdot v$$

$$t \in I \rightsquigarrow T: V \rightarrow V$$

$$T \sim (\cong) T \text{ de } \begin{matrix} w^3 \\ \text{opp} \end{matrix}, \begin{matrix} w^6 \\ \text{opp} \end{matrix} \text{ if } \begin{matrix} \Rightarrow \\ \text{opp} \end{matrix} \text{ or } \begin{matrix} \Rightarrow \\ \text{opp} \end{matrix} \text{ if }$$

$\text{SC}, \text{TR} \subseteq \text{rec } \alpha - c \quad \wedge' \cup$

$q = \bigcap_{\alpha < \omega} \gamma \cap : \text{fin } \text{kg } \text{TR} - \alpha$

$0 \neq \bar{q} \in V \quad \text{SC}$

$(\text{TR} - \alpha) \bar{q} = \text{TR} = 0$

$f_a(x) = x^n + x^{n-1} - a = 0 \quad \begin{cases} \text{if } \\ \alpha > 0 \end{cases}$

$n \geq 2$

$\text{rec } p \cap \text{rec } c \cap \text{rec } f, i$
 $\vdash (a) \quad \text{rec } \vdash \text{in } \text{in } \text{in }$

$\perp \vdash n \text{ for } r \quad \text{for } \text{exists } \eta \text{ do } z$

$$f_a'(0) = -a < 0$$

. 1

$$f_a'(x) = nx^{n-1} + (a-1)x^{n-2} = 0$$

$$x=0 \text{ 时 } n x^{n-1} = 0$$

$$x = \frac{1-a}{n} < 0$$

由上推断出

$$(d\varphi/dx)(a) = \left| \frac{a \cdot r'(a)}{r(a)} \right| < \frac{1}{n-1}$$

$$F(x, a) = x^n + x^{n-1} - a$$

$$F(r(a), a) = 0 \quad \overbrace{r(a)^n + r(a)^{n-1}}^{n-1} - a = 0$$

$$\cancel{r(a)^n + r(a)^{n-1}} - a = 0$$

$$r'(a) \cdot n \cdot r(a)^{n-1} + r'(a) \cdot (n-1)r(a)^{n-2} =$$

$$| = 0$$

$$r'(a) \approx \frac{|}{nr(a)^{n-1} + (n-1)r(a)^{n-2}}$$

$$\frac{ar^{n-1}}{r(a)} = \frac{a}{nr(a)^n + (n-1)r(a)^{n-1}} =$$

$$\frac{r(a)^n + r(a)^{n-1}}{nr(a)^n + (n-1)r(a)^{n-1}} \leq \frac{\cancel{r(a)^n} + \cancel{r(a)^{n-1}}}{\cancel{n-1}(r(a)^n + r(a)^{n-1})} =$$

$n - \gamma > e^{\gamma} / 3$ $\rho / \sqrt{d} \approx T_k$

? $T_n \circ T_m$ $\approx \sqrt{d}$, \sim

need δ : $T_n > e^{\gamma} / 3 \approx \sqrt{d}$

$\varphi_n(z) = z^n$ for $\delta_{n,0}$

$z \in S' \subseteq \mathbb{C}^*$ def

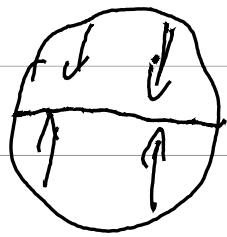
$\sqrt{d} \approx n^{1/k}$ $\approx \sqrt{d}$

arg(z) $\approx \pi/2$ $\Rightarrow z \approx \frac{1}{2}$

S' $\approx \{-1\}$ $\approx \{1\}$ $\Rightarrow \mathbb{C} \setminus \{0\}$

$\pi(z) = \frac{z + \frac{1}{z}}{2} \approx \frac{z + \overline{z}}{2} = \underline{\operatorname{Re}(z)}$

$$z + \frac{1}{z} = a \quad (\Rightarrow z^2 + 1 - az = 0)$$

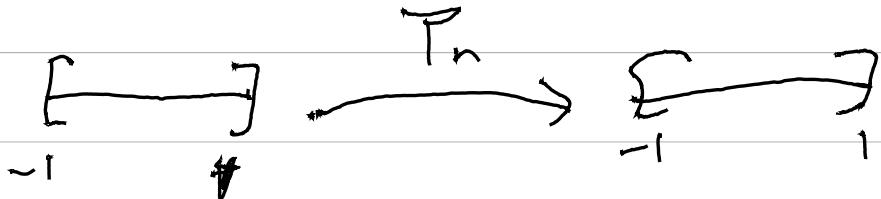
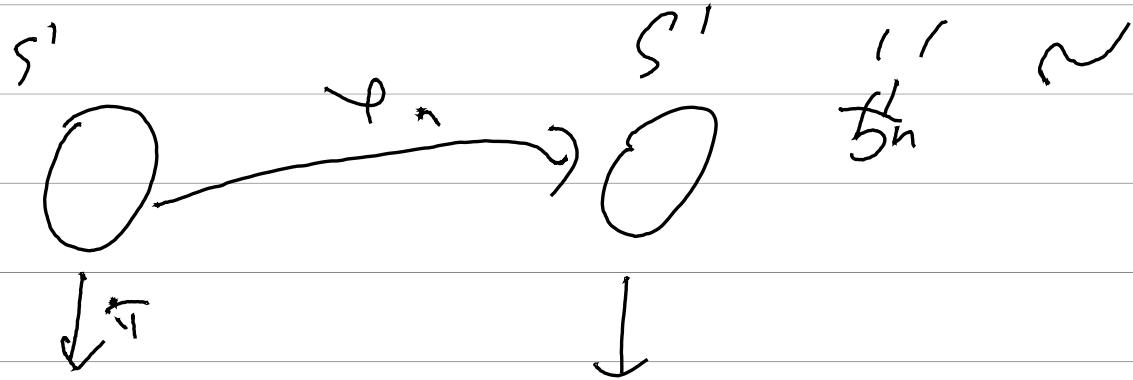


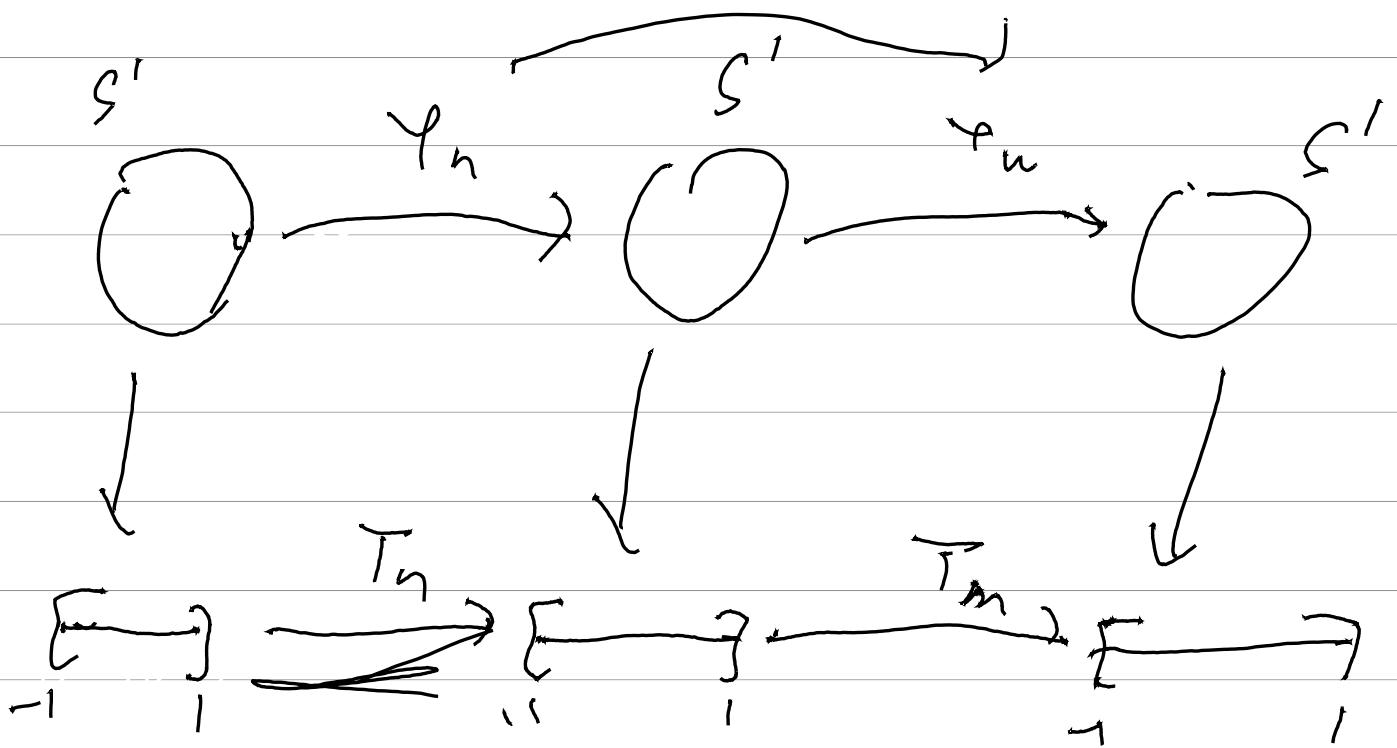
SIC amb \mathcal{E}_C , sv 73x

$$a = \frac{1}{b}$$

$$\varphi_n(b) \approx \varphi_n(a)$$

$$a^n \quad b^n$$





$$\varphi_m \circ \varphi_n = \varphi_{m+n}$$

SC

$$T_m \circ T_n = T_{m+n}$$

$$T_n \left(\frac{z + \frac{1}{2^n}}{2} \right) = \frac{z^{2^n} + \frac{1}{2^{2n}}}{2}$$

$$T_m \left(\frac{z^{2^n} + \frac{1}{2^{2n}}}{2} \right) = \frac{z^{2^{mn}} + \frac{1}{2^{mn}}}{2}$$

$$f(x) = e^x \quad .56$$

$$[t, t+1, \dots, t+n] f = \frac{(e-1)^n}{n!} e^t$$

$$\{e\}f = f(t) = \frac{(e^{-t})^0}{0!} e^t$$

$$[t, \dots, t+n] f = \frac{[t+1, \dots, t+n] f - [t, \dots, t+n-1] f}{(t+n) - t} =$$

$$\frac{(e-1)^{h-1}}{(h-1)!} e^{t+1} - \frac{(e-1)^{h-1}}{(h-1)!} e^t = e^t \cdot \frac{(e-1)^h}{h!}$$

$\cup_{n \geq 1} I_n \rightarrow$

$$\{0, \dots, n\}(f) = \frac{f^{(n)}(\xi)}{n!} \quad \xi \in (0, n)$$

11

11

$$\frac{(e-1)^n}{n!}$$

$$\frac{e^\xi}{n!}$$

$$\xi = \log((e-1)^n) = n \log(e-1)$$

$$\log(e-1) < \frac{1}{2}$$

$$\frac{3 \pm \sqrt{5}}{2}$$

$$e-1 < \sqrt{e}$$

$$(e-1)^2 < 2$$

$$e^2 - 3e + 1 < 0$$

~~mix~~
A \rightarrow A' \rightarrow $R^T Q$ \rightarrow $R Q$
 \leftarrow P and Q \leftarrow $R^T Q$

$$\underbrace{A^n}_{\sim} x = b$$

$n \ll m$



$$A x = b$$

α

$$A^{k-1} y = b \quad QR$$

$$A y = b$$

$$A'$$

$$A^{\frac{n}{2}} y = b$$

$$A = Q^T R Q$$

$$A^{\frac{n}{2}} x = y$$

$$A = Q R$$

$$R^A$$

$$G(x, y) = 0$$

$$G(v_0, y_0) = 0$$

$$G_y(x_0, y_0) \neq 0$$

$$G(x, u(x)) = 0$$

$$u_n(x) \rightarrow u(x)$$

G_1

$\underbrace{u_n(x)}_{\text{---}} \xrightarrow{\text{---}} u(x)$

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x)}$$

is -> / ↗↗ very

$$P_1(x_1, \dots, x_n) = 0$$

:

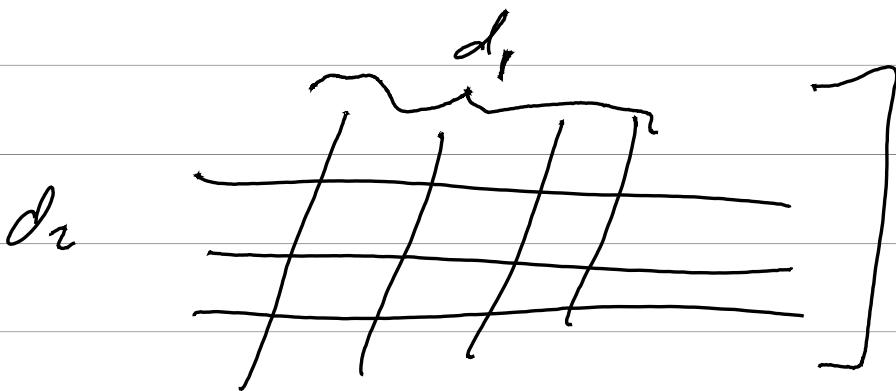
$$P_n(x_1, \dots, x_n) = 0$$

is Göttingen \cong for

$(\cup \cap \cup \cap)$ $\cong \mathbb{P}^n$

πd_i

(is \cong) $d_i = \deg(P_i)$ \cong



Nicen norm n'f'han

$$q_i = 0$$

d_i se referem a_i Σ reduz
für nicht norm reduz

reduz

$$\bar{q} \cdot (1-t) + \bar{p} \cdot t$$

$$\text{Def} \quad A = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \xrightarrow{\text{red}} \underline{\{1\}}$$

linear λ λ λ

$$A \begin{pmatrix} x \\ y \end{pmatrix} = \lambda \begin{pmatrix} x \\ y \end{pmatrix}$$

$b \neq 0 \Leftrightarrow (0, 1)$ λ
 $x=1$ λ λ

$$\left. \begin{array}{l} (1) ax + by = \lambda x \\ (2) cx + dy = \lambda y \\ (3) ux + vy = 1 \end{array} \right\}$$

$$X = \frac{x_0}{z}, Y = \frac{y_0}{z}, \lambda = \frac{\lambda_0}{z}$$

↓

$$0 = \underbrace{a z X_0 + b z Y_0}_{c z X_0 + d z Y_0} = \lambda_0 X_0 \quad \leftarrow 2$$

$$c z X_0 + d z Y_0 = \lambda_0 Y_0 \quad \leftarrow 2$$

$$\underbrace{u X_0 + v Y_0 = z}_{\text{---}} \quad \leftarrow 1$$

3' (n, p) mind $\varphi : \mathbb{S}^2$

$$\text{mind } 2^n \quad \text{1'} \quad n \times n$$

(Conv. 's)

mind $n \rightarrow \mathbb{N} \rightarrow \mathbb{S}^1 : \text{fold}$

$$\underbrace{\lambda_0 = 0}_{\text{---}} \quad \text{if } Y_0 = 0 \quad : z = 0$$

$$(X_0 = 0)$$

$$A \begin{pmatrix} x \\ y \end{pmatrix} = \underline{\lambda} \begin{pmatrix} x \\ y \end{pmatrix}$$

\rightarrow x_0, y_0 is eigenvector of A

$$\underline{\underline{\mathbb{P}^1}} \times \underline{\underline{\mathbb{A}^1}} \subseteq \underline{\underline{\mathbb{P}^1}} \times \underline{\underline{\mathbb{P}^1}} \subseteq \underline{\underline{\mathbb{P}^3}}$$

$$[x, y] \underbrace{\hspace{1cm}}_{\lambda}$$

$$\mathbb{P}^1 = \mathbb{C} \cup \{\infty\}$$

$$\mathbb{P}^n = \mathbb{C}^n \cup \mathbb{P}^{n-1}$$

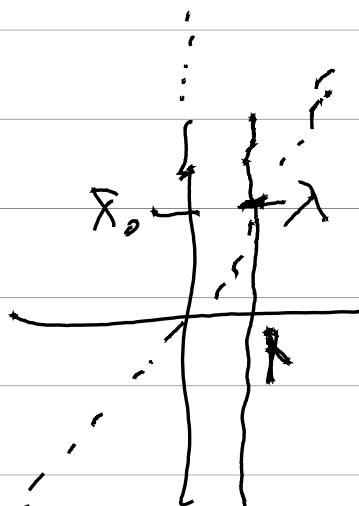
$$\left. \begin{array}{l} ax_0 + by_0 = \lambda_0 x_0 \\ cx_0 + dy_0 = \lambda_0 y_0 \\ ex_0 + fy_0 = e \end{array} \right\}$$

$$x = \frac{x_0}{z} \quad y = \frac{y_0}{z} \quad \lambda = \frac{\lambda_0}{d}$$

$$a \frac{x_0}{z} + b \frac{y_0}{z} = \frac{\lambda_0}{d} \cdot \frac{x_0}{z}$$

$$c \frac{x_0}{z} + d \frac{y_0}{z} = \frac{\lambda_0}{d} \cdot \frac{y_0}{z}$$

$$e \frac{x_0}{z} + f \frac{y_0}{z} = 1$$



$$\{x_1, \dots, x_n\}, \{x_{n+1}, \dots, x_n\}, \dots \tilde{P}(x_1, \dots, x_n) = 0$$

P_i

di

$q_i = \frac{\partial^i}{\partial x^i} P(x)$: گون
اینها را برای این سه گونه داریم

که از آنها میتوان

$$\{x, y\} \mapsto \lambda^3 + \lambda^2 + \lambda + 1, \text{ که دلیل این}$$

$$\{\lambda^2 - 1\}$$

$$(1) \rightsquigarrow \underbrace{\ell_1(x, y)}_{\text{که از آنها}} \underbrace{\ell_2(\lambda)}_{\text{که از آنها}} = 0 \quad \left. \begin{array}{l} \text{که از آنها} \\ \text{که از آنها} \end{array} \right\} \text{که از آنها}$$

$$(2) \rightsquigarrow \underbrace{\ell_3(x, y)}_{\text{که از آنها}} \underbrace{\ell_4(\lambda)}_{\text{که از آنها}} = 0$$

$$(3) \rightsquigarrow \underbrace{\ell_5(x, y)}_{\text{که از آنها}} = 0$$

و همچنان در مورد دیگر اینها را میتوان از آنها استفاده کرد.

PUMA CTN 17

$$x_1^2 + x_2^2 - 1 = 0$$

$$x_3^2 + x_4^2 - 1 = 0$$

$$x_5^2 + x_6^2 - 1 = 0$$

$$x_7^2 + x_8^2 - 1 = 0$$

$$a x_1 x_3 - b x_2 x_3 - c x_1 - d x_2 - e x_4 + x_7 - f = 0$$

$$g(x_1 x_3 + x_2 x_3 + \{x_1 - x_2 - x_4 - 2\} = 0$$

$$x_6 x_8 + \{x_1 + \{x_2 - 0\}$$

$$\{x_1 + \{x_2 + \{ = 0$$

$$\{x_1, x_2\}, \overline{x} - \{r'\}, \text{and } \{x_3, x_4, x_7, x_8\}, \{x_5, x_6\}$$

$$\underline{\ell_1(x_1, x_2)} \quad \ell_2(x_1, x_2) = 0$$

$$\rightarrow \underline{\ell_3(x_3, x_4, x_7, x_8)} \quad \ell_4(x) = 0$$

$$\rightarrow \underline{\ell_5(x_5, x_6)} \quad \ell_6(x_5, x_6) = 0$$

$$\rightarrow \underline{\ell_7(\bar{x})} \quad \ell_8(\bar{x}) = 0$$

$$\begin{array}{c} 2 \\ \{x_1, x_2\} \end{array} \quad 4 \quad \begin{array}{c} \bar{x} \cdot 2 \\ \{x_5, x_6\} \end{array}$$

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$$a x_1 x_3 - b x_2 x_3 - c x_1 - d x_2 - e x_4 + x_7 - f = 0$$

$$\{x_1, x_2\}, \overline{x} - \{r'\}, \text{and } \{x_3, x_4, x_7, x_8\}, \{x_5, x_6\}$$

$$\underline{\ell_9(x_1, x_2)} \cdot \ell_{10}(\bar{x}) = 0$$

$$\underline{\ell_{11}(x_1, x_2)} \quad \ell_{12}(\bar{x}) = 0$$

$$\underline{\ell_{12}(x_1, x_2)} \cdot \underline{\ell_{14}(\bar{x})} \cdot \underline{\ell_{15}(x_5, x_6)} = 0$$

$$\underline{\ell_{16}(x_1, x_2)} = 0$$

p_i $\sim N(110, 10)$ $r \approx 0.55$ $|x|/r^2$

new s_j $\sim N(\mu_j, \sigma_j^2)$ λ_j/\sqrt{r}

$$d_{ij} = \deg(p_i, s_j)$$

$$s_1, \dots, s_k \quad \text{new} \quad D = (d_{ij})_{\substack{i=1, \dots, n \\ j=1, \dots, k}}$$

raw \rightarrow new

$$\text{Per}(D) =$$

n_1 \rightarrow λ_1
 $n_2 \rightarrow \dots \rightarrow n_k$

high $\rightarrow \dots \rightarrow$ low
new \rightarrow old

old \rightarrow new

$$\text{Per} \begin{pmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 2 \\ 0 & 2 & 0 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix} = 2_{(1,1)} \cdot 1_{(8,1)} \cdot 2_{(2,2)} \cdot 2_{(4,2)} \cdot 1 \cdot 1 \cdot 2 \cdot 1 = 16$$

ר) סדרת נסיגה שבסופה

הנושאים נאמרים נורו

(Per ר' נסיגת סינון כוכב ירושלים)

עליה מלחין יוסי עזג'ה

זה ה' נושא

$\lambda_1 \lambda_2 \lambda_3$ ရှိခဲ့ကြသည် A ပေါ်လုပ်နည်း

SLC

$$\text{Per}(A) \approx \sum_{\sigma \in S_n} \prod_{i=1}^n a_{i, \sigma(i)}$$

$(\pi^n) \text{Ref} \rightarrow d' \text{C} \sqrt{\epsilon} r^2 / (f)$

Lotka-Volterra လုပ်နည်း

$$x_1 x_2^2 + x_1 x_3^2 - 7x_1 + 1 = 0 \quad (x_1)(x_2, x_3)$$

$$x_2 x_1^2 + x_2 x_3^2 - 7x_2 + 1 = 0 \quad (x_2)(x_1, x_3)$$

$$\underbrace{x_3 x_1^2 + x_3 x_2^2 - 7x_3 + 1 = 0}_{(x_3)(x_1, x_2)}$$

$$\left. \begin{array}{l} l_1(x_1) l_2(x_2, x_3) \underline{l_3(x_2, x_3)} = 0 \\ l_4(x_2) \underline{l_5(x_1, x_3)} l_6(x_1, x_3) = 0 \\ \underline{l_7(x_3)} l_8(x_1, x_2) l_9(x_1, x_2) = 0 \end{array} \right\} \bar{q}(x_1, x_2, x_3)$$

$$l_2(x_2, x_3) = ax_2 + bx_3 + c$$

$$l_2(x_3) = dx_3 + e$$

$$x_3 = -\frac{e}{d}$$

$$x_2 = \dots$$

$$F(\bar{x}, t) = q(\bar{x})(1-t)^{-1} + p(\bar{x})$$

$$F(\bar{x}, 0) = \underline{q(\bar{x})}$$

$$F(\bar{x}, 1) = \underline{p(\bar{x})} \quad \bar{x}(0) = \bar{x}_0$$

