

principles

Walter Gautschi

maths prof in 1952 - 1970

... member of the ICM, 1970

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

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

integrals, numerical methods -  
books, etc., about numerical methods  
including error analysis, 1970

1971, first book: "Numerical Analysis" -  
numerical methods, error analysis, 1971, 1973  
including numerical methods, 1971, 1973

الله يحيى

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

23) If  $\gamma$  is a curve in  $\mathbb{R}^n$  -  $\gamma'(t) \neq 0$   $\quad \mathbb{R}^n \subseteq \mathbb{R}$

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

$\kappa$  (condition number)  $x \rightarrow$

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

$(x, f(x) > 0 \rightarrow \text{interval } \text{near})$

,  $f(x) = ax+b$  case 1

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

" for 2nd case case 2

$$I_n = \int_0^1 \frac{t^6}{t+5} dt$$

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

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

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

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

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

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

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

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

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

$$k \gg n$$

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

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

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

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

$a_1$

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

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

$V = 0 \quad \|V\| = 0 \quad \text{1.1}$   
 $\|av\| = |a| \cdot \|v\| \quad \forall v \in V, a \in \mathbb{R} \quad \text{1.2}$   
 $\forall v \in V \quad \text{1.3}$

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

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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  $\|\cdot\|$  euclidean norm  $\Rightarrow$  distance

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

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

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

设  $\gamma/\Gamma_\beta$  为  $\gamma$  的 单位向量

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

该类型的  $\gamma/\Gamma_\beta$  的范数

$v \in V - \{v_i\}$  时有  $\|v\|_i$ .

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

由  $\gamma/\Gamma_\beta$  为  $\gamma$  的单位向量

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

$\mathbb{R}^d$  为  $\gamma/\Gamma_\beta$  的 单位圆盘

该圆盘的

$\mathbb{R}^d$  为  $\gamma/\Gamma_\beta$  的 单位圆环

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

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  $T: U \rightarrow V$

רְאֵבָבָה, וְנִזְנַתְּנָהָה, וְגַדְעָה, וְכַלְמָה, וְבַשְׂרָבָה.

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

$$\text{N}^{\text{H}}\text{O}\text{S} \text{S} \text{N} \text{P} \text{O} \text{S} \text{N} \rightarrow \text{Hom}(\underline{\text{U}}, \text{V})$$

గనించు ట్రాక్టర్లు నుండి వెళుత్తాము.

הנתקן נסח

ת ש 23 ניון ינואר

1(17) x 12/12

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

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

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

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

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

und  $\|\tau^{-1}x\|$  für  $\tau x = b$

$b$  ist die ursprüngliche Vektoren

?  $b^*$  ?

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

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

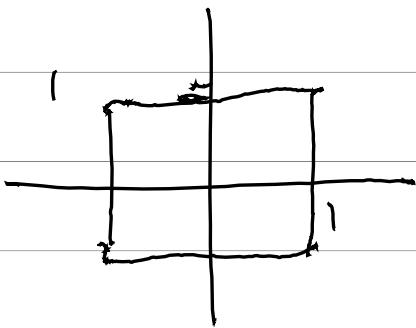
$$\text{Cond}_2 \tau_n = \frac{(V_2 + 1)^{n+4}}{\sum_{k=1}^{n+4} k \cdot \sqrt{\tau_n}}$$

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  $\mathbb{R}^m$

$$\left( a_{ij} \right)_{\substack{1 \leq i \leq n \\ 1 \leq j \leq m}} \rightarrow \text{3x3}$$



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



$$X = 17$$

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

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

$$y = -17 + 8$$

$$2 \cdot 17 = 34$$

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

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

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

$\text{cond}(T)$

$$[1 \cdot 1]$$

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

Übung 3

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

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

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

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

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

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

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

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

↑ ↗ ↘ ↗ ↘ ↗

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

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

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

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

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

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

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

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

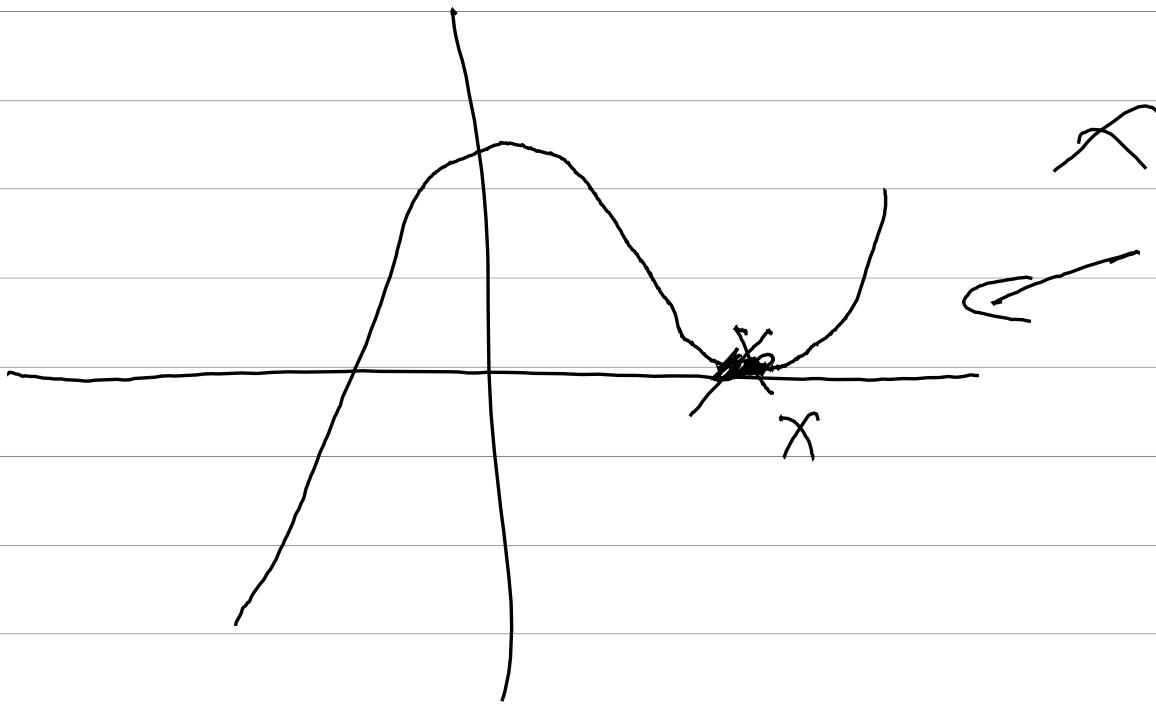
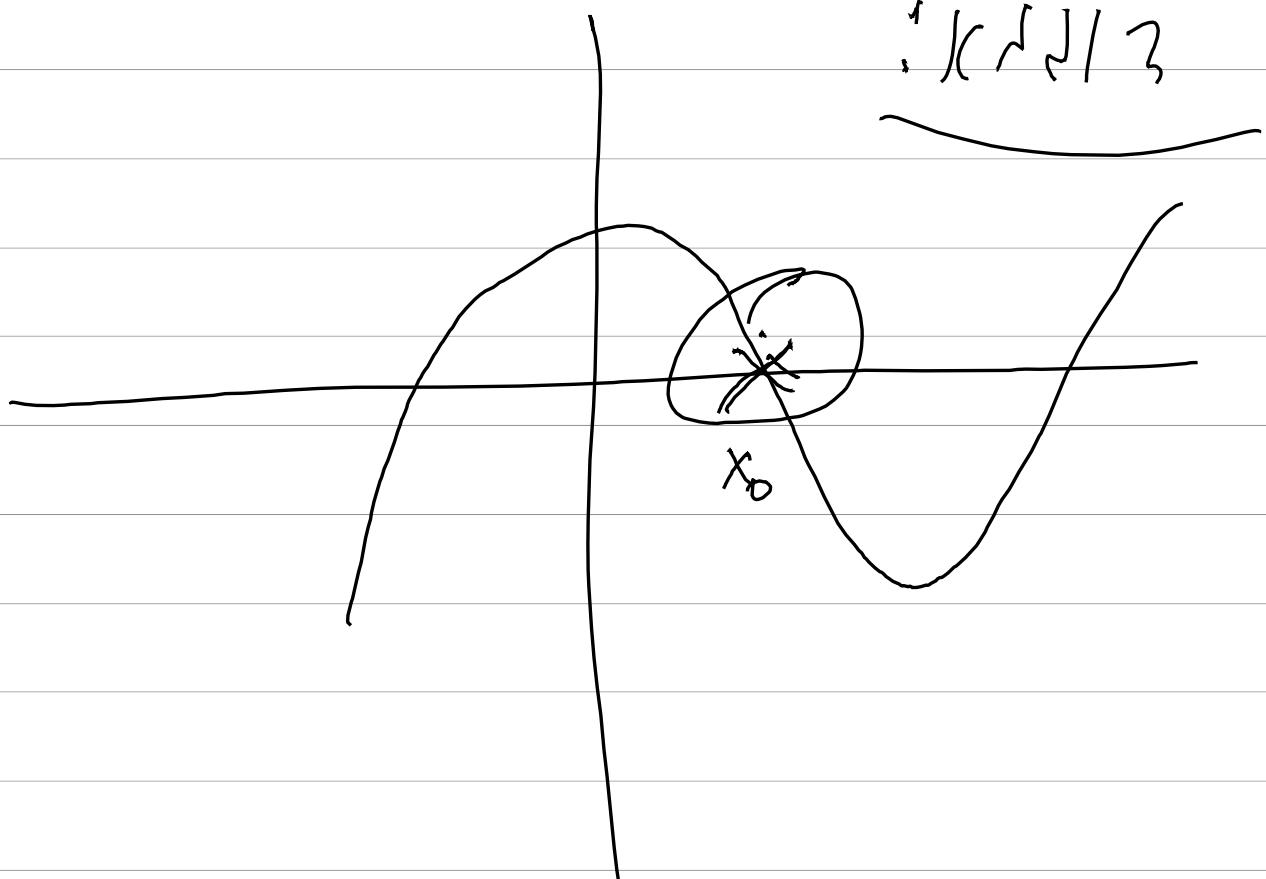
$$\text{cond}_x(f) = \frac{|x| \cdot \frac{1}{x^2}}{\left|\frac{1}{x} + \frac{1}{y}\right|} \quad \frac{|y| \cdot \frac{1}{y^2}}{\left|\frac{1}{x} + \frac{1}{y}\right|}$$

||

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

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

$\therefore K \cap J / 3$

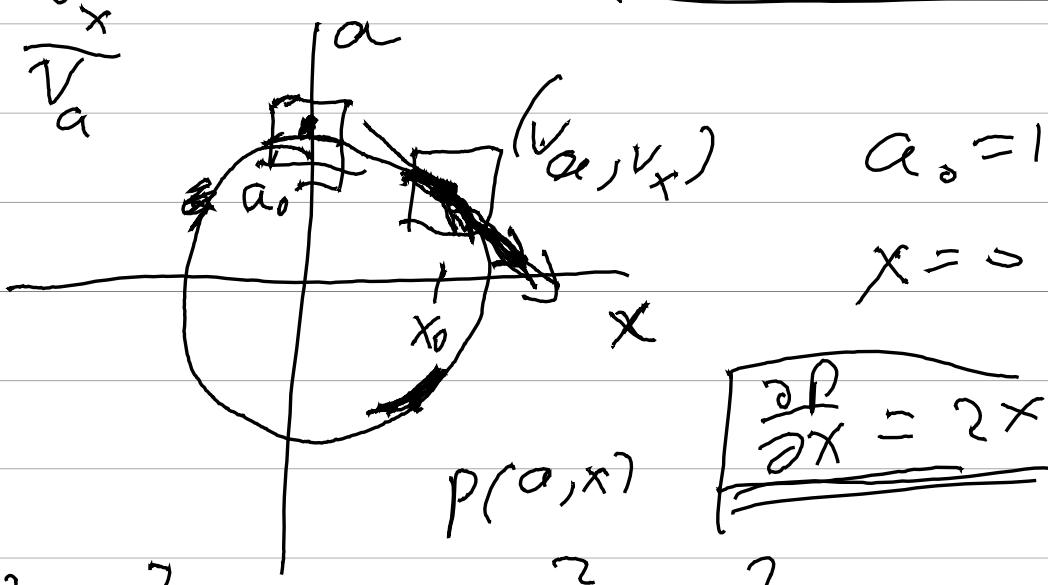


$h \rightarrow \infty ?$   $n' r > 1/p$

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

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

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



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

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

$$x = x(a)$$

$$x_0 = x(a_0)$$

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

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

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



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

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



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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

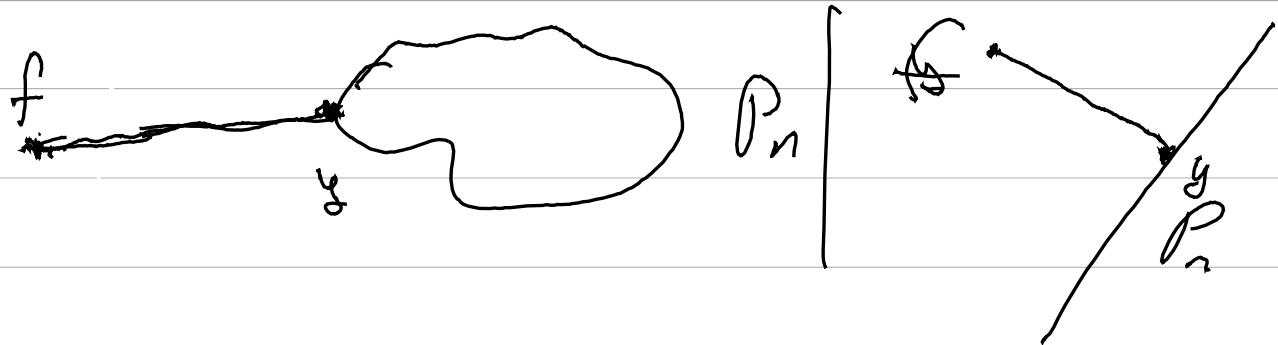
$$P = \bigcup P_i \quad P_0 \subseteq P_1 \subseteq P_2 \dots$$

3.2) 0 in NN  $\rho_n$  in

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

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

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



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

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

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

$\|f\|_{C(X)} = \inf \left\{ M : \|f - g\|_1 \leq M \right\}$

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

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

$f \in P \quad \forall x, y \in X \quad x \neq y \Rightarrow |f(x) - f(y)| < \epsilon$

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

$\underline{\text{Definition of } P}$

$\rho, \rho_1, \rho_2 \in P \quad \exists \delta > 0 \quad \forall x, y \in X \quad |x - y| < \delta \Rightarrow |\rho(x) - \rho(y)| < \epsilon$

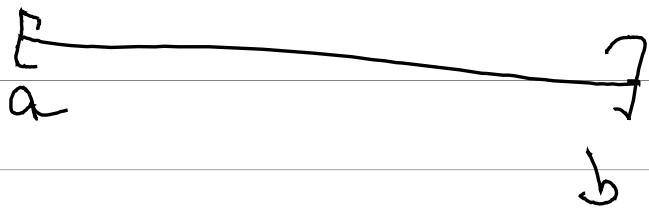
$\rho \in P \subseteq C(X) \quad \text{Since } \rho \text{ is continuous}$

$C(X), f \in \mathcal{F} : C(X) - \sup_{x \in X} |f(x)| < \delta$

$\exists \rho > 0 \quad \forall x \in X \quad \forall f \in \mathcal{F}$

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

$|f(x) - p(x)| < \varepsilon \quad \forall x \in X \quad \forall f \in \mathcal{F}$



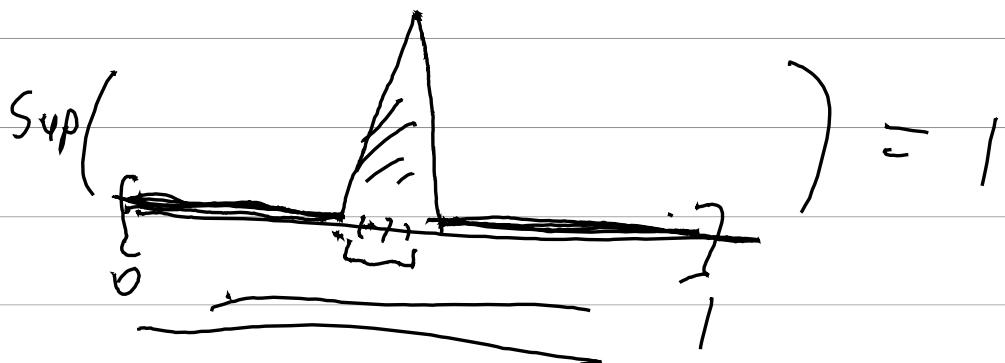
ההסבובים נקראים כרונומטרים

הכרונומטר מודולרי

הכרונומטר מודולרי הוא מכשיר המורכב ממספר מודולים.

הנורמליזציה

הו



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

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

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

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

ונורמליזציה  $x \rightarrow \bar{x}$

$\mathbb{R}^n \rightarrow \text{ну}$   $\bar{x} \rightarrow \frac{\bar{x}}{\|\bar{x}\|_p}$

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

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

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

~~X~~

$\therefore \rho(F) \approx X = \{1, 2, \dots, n\} \quad \text{and}$

$\rho(F) \approx L_2 \approx \mathbb{R}^n \cap \mathbb{R}^n$

$\forall f \in \text{real } \mathbb{C}, \exists \omega \in \mathbb{R}^n \quad f(x) = \int_{\mathbb{R}^n} f(x) \omega$

$\therefore \omega : X \rightarrow \mathbb{R} \quad \lambda \omega / \omega \quad \lambda \omega / \omega$

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

~~X~~

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

$$\|f\|_\omega^2$$



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

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

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

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



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՛վ

$v \mapsto \|v\| := \sqrt{\langle v, v \rangle}$  ՀՊՀ ՀՇ

.  $V$  հայելա ՀՇ

$u, v \in V$  Ֆ , ՀՇ ՀՇ

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

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

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 of  $A^T A$ )

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

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

Matrix diagonalization,  $\lambda$   $\beta$

Orthogonal matrix  $U$ ,  $\lambda$   $\beta$

$$[P_n | \sqrt{\lambda}] \underbrace{P_n^{-1}}_{\{ \pi_i \}} \quad \{ \pi_i \}$$

$f \in A$

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

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

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  $f$

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

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

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

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

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

$$S \subset \tilde{X} \neq \emptyset \quad \text{and}, \quad \text{w.l.o.g}$$

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

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

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

i)  $\mu\sigma$   $\Rightarrow \sigma \text{ is } A$ ,  $\exists x$   
 $\forall x \forall y$

$(\pi_i)$   $i \geq 0$

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

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

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

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

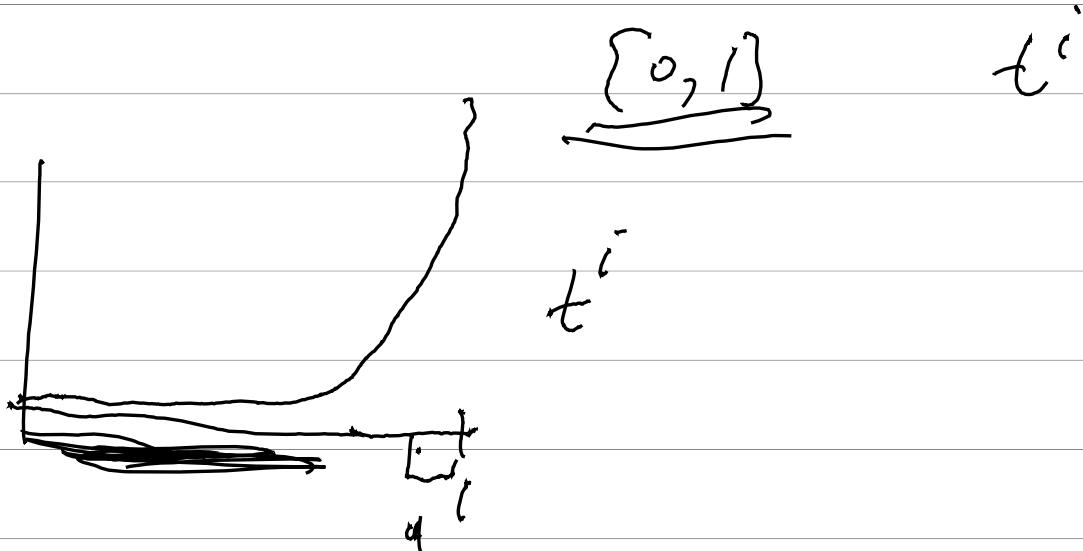
$$\langle \pi_i, \pi_j \rangle = \int_0^{i+j} dt = \frac{t^{i+j+1}}{i+j+1} \Big|_0^1 =$$

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

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

$\Rightarrow$   $C^{-1}$   $\rightarrow$   $\text{def}$   $\text{matrix}$   $\Rightarrow$   $3 \times 3$

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



co &  $\Rightarrow$  ? NYF ;/ 120

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

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

$$f = \sum_i a_i \pi_i$$

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

$$\pi_1, \pi_2, \dots \in C_{NC} = \{ \pi_i \mid \langle \pi_i, \pi_i \rangle = 1 \}$$

$$\sum_{i=1}^n \pi_i = 1$$

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

$$\hat{\pi}_{k+1} = \pi_{k+1} - \sum_{i=1}^k \frac{\langle \pi_{k+1}, \hat{\pi}_i \rangle}{\|\hat{\pi}_i\|^2} \hat{\pi}_i$$
$$\langle \hat{\pi}_{k+1}, \hat{\pi}_i \rangle = \langle \pi_{k+1}, \hat{\pi}_i \rangle - \frac{1}{\|\hat{\pi}_i\|^2} \langle \pi_{k+1}, \pi_i \rangle = 0$$

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

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

$$\dim(P_i) = i$$

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

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

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

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

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

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

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

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

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

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

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

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 can write  $\pi_k$   $\in$   $\mathcal{S}'$

thus we have  $\langle f, \pi_k \rangle$

$\forall c \neq 0$   $\Rightarrow$   $\langle f, c\pi_k \rangle$

$\text{Real } [-1, 1] \rightarrow \mathbb{C}$  is  $\{k\pi/3\}$

$(f(0), f(\pi/3), f(2\pi/3))$   $\rightarrow$   $\mathbb{R}^3$

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

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

从  $\pi_k$  到  $t^k$ , 令  $t^k$  为  $\pi_i$  的

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

$$\dots = 0$$

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

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

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

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

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

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

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

Wichtigste Ergebnisse

if  $\alpha < \omega$  for all  $\gamma < \omega$  is

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

↓ . t ↗

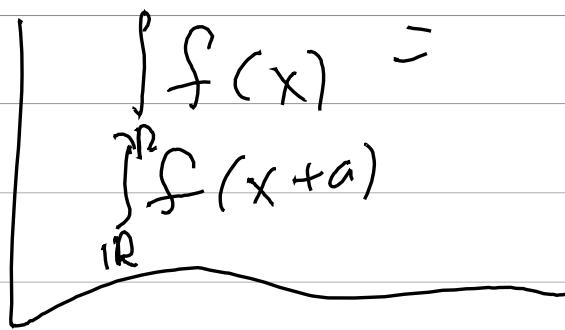
$$f: [0,1] \rightarrow \mathbb{R} \quad f(0) = f(1)$$

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

(=)

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

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



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

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

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

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

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

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  $x^n$

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

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

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

$$\langle f, g \rangle = \int_{\mathcal{S}'} f, \bar{g}$$

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

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

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

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

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

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

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

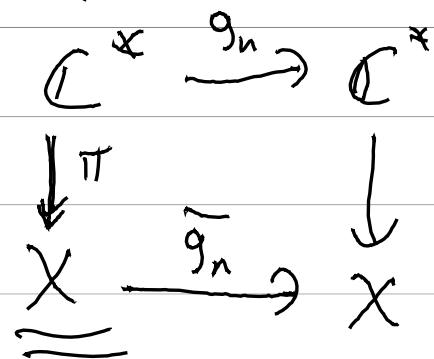
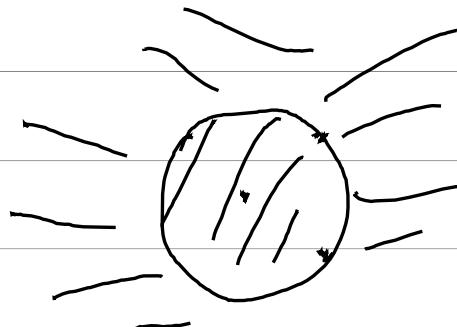
$\therefore f(z) \neq$

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

If  $x=y$   $\Rightarrow c \neq \infty$   $\Rightarrow z \sim y$

$$x = \frac{c}{z}$$

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



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

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

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

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

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

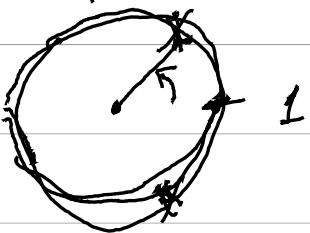
$\int_{-1}^1 f g \frac{1}{\sqrt{1-y^2}} dy$   $\sim \int_{-1}^1 f g dy$

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

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

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

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



$\downarrow P$

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

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

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

$x$

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

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

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

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

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

$\frac{1}{2}$

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

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

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

$\varphi_n(x) = x^n$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

'3' für f src  $\approx 317$

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

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

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

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

$$P_i(x) = \frac{\prod_{j \neq i} (x - c_j)}{\prod_{j \neq i} (c_i - c_j)} \in P_n = \mathbb{R}[x]^n$$

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

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

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

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

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

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

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

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

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

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

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

برهان انتقالی

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

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

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

$c_i \neq x \quad x \geq c_i \quad \underline{i > n/2}$

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

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

マハガル  $\Rightarrow G$  の  $\approx$  は  $c_i$

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

$G^{(n+1)}$   $- f : \mathbb{R} \rightarrow \mathbb{C}$  が

$\{ \quad \text{odd } e'$

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

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

$t = \zeta$   $\omega_{\lambda}(\zeta)$

$\zeta \in [a, b]$

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

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

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

$$= \int_{\gamma_0} f \circ \tilde{\gamma} \in \mathbb{C}^{(n)}_{\sum a_i b_i} \cap \mathcal{Z}^0$$

$$:= \int_{\gamma_0} f \circ \tilde{\gamma} = \int_{\gamma_0} f \circ \tilde{\gamma} \circ \tilde{\gamma}' \circ \tilde{\gamma}'^{-1}$$

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

$$\int_{\gamma_0} f \circ \tilde{\gamma} \circ \tilde{\gamma}' \circ \tilde{\gamma}'^{-1}$$

$$\pi_{\tilde{\gamma}} \circ \tilde{\gamma}'$$

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

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

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

-c ρ' 31n sic

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

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

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

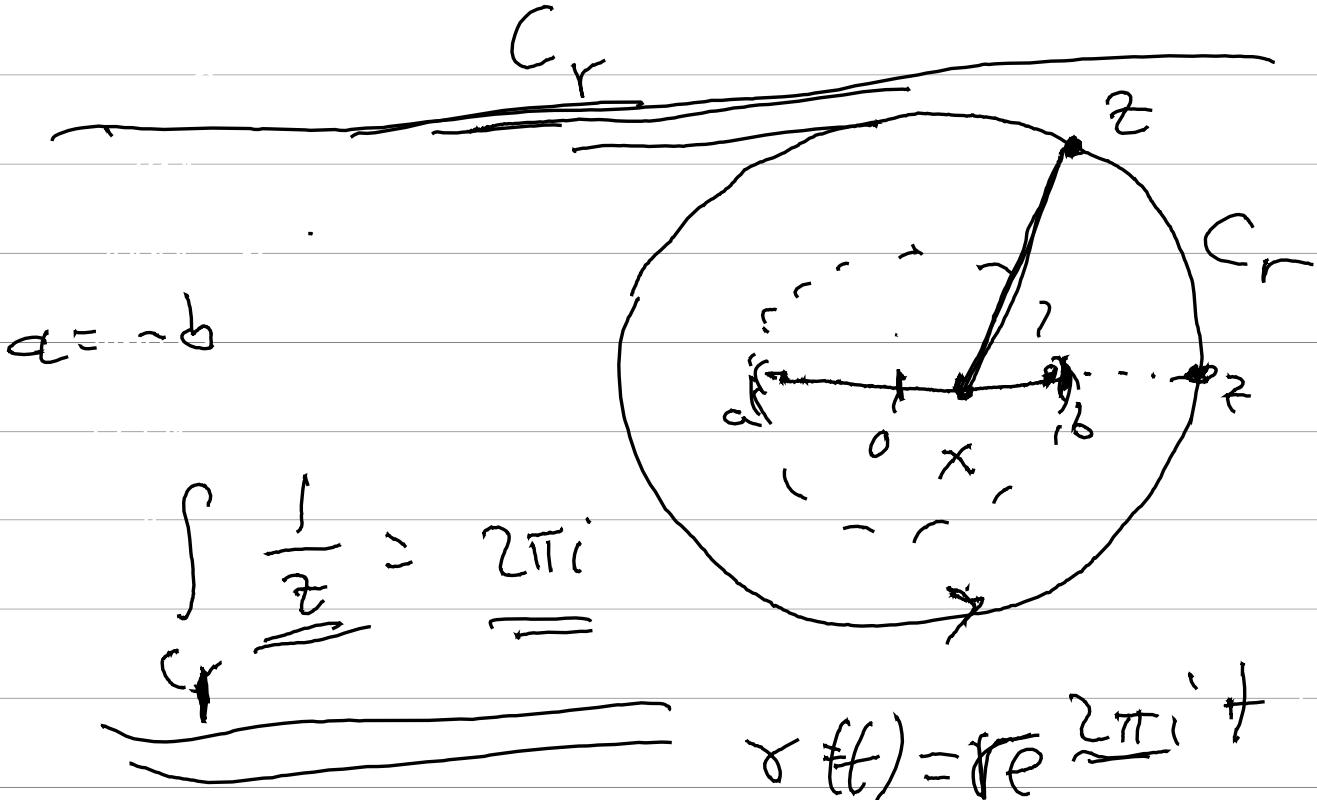
$$m_n = \|f^{(n)}\|_{\infty}$$

ר' סיסיק גאנז לנ' א' f

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

$S/\ell$

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



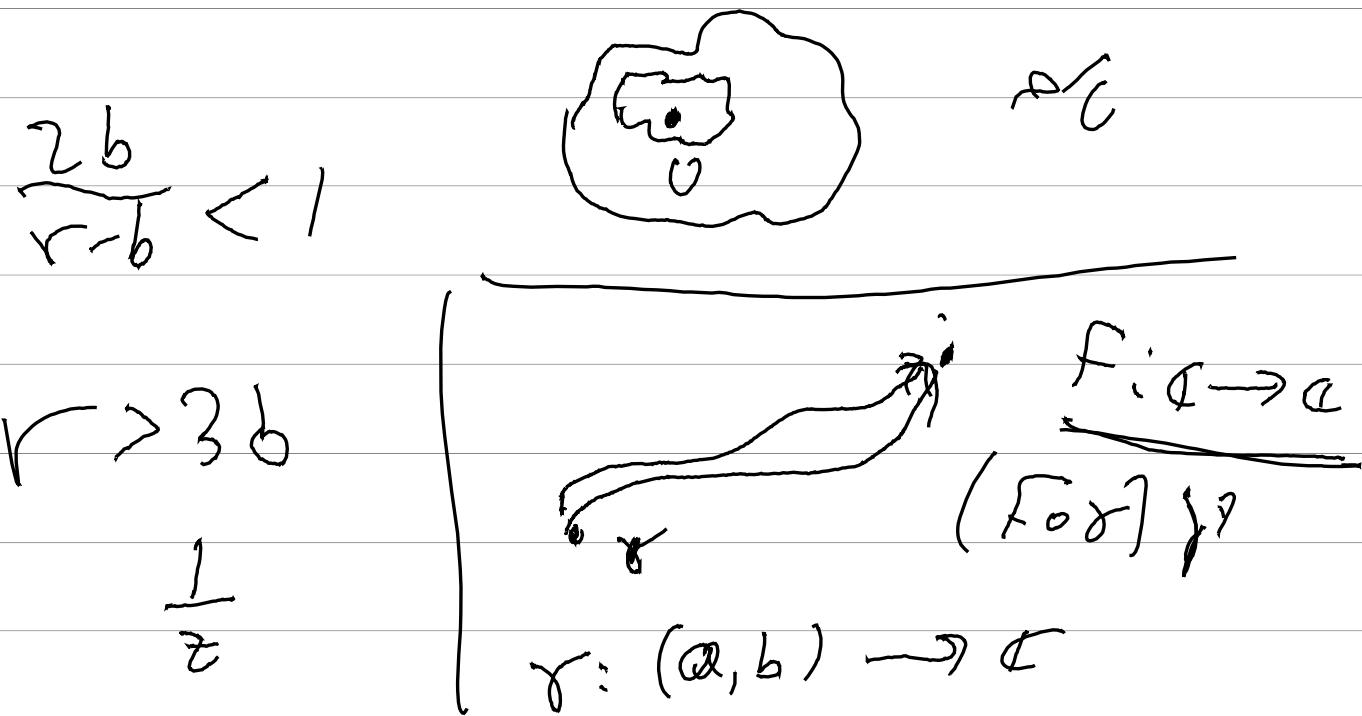
$$\underbrace{\|z-x\|}_{\geq r-b}$$

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

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

$n!$

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



רְאֵבָבָה | גִּבְעָה אֶלְגָּרָה לְנָ

$([-1, 1] \setminus \{0\})$  || • 160 גַּוְתָּה נ

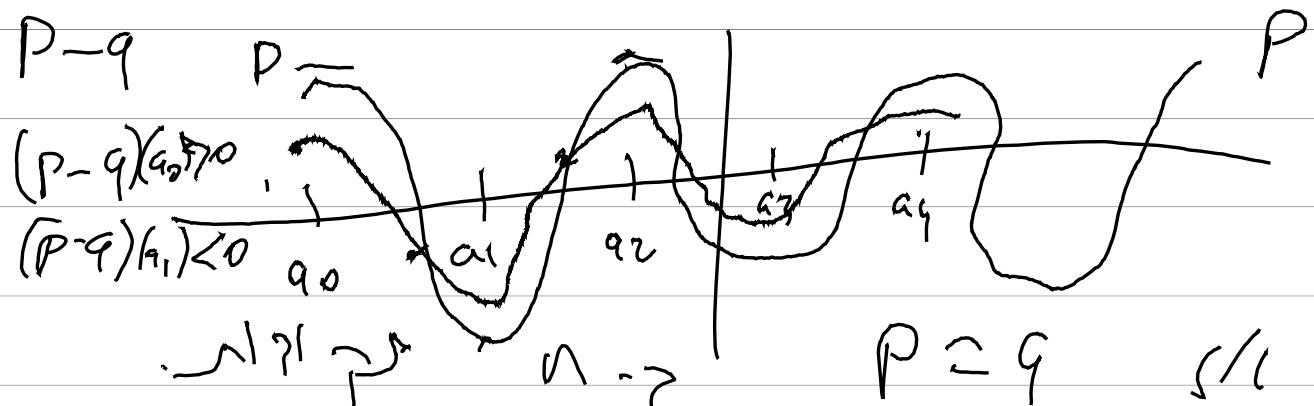
? גְּדֹלָה;

רְאֵבָבָה | גִּבְעָה אֶלְגָּרָה P אֶלְגָּרָה

ולא  $\|P\|_\infty = |P(a_i)|$  -& > n  
 $P(a_i) = -P(a_{i+1})$   
 $P$  ס/י  $a_i$  מ/פ/ $P$  n+1

רְאֵבָבָה  $\|P\|_\infty$  וְאֶלְגָּרָה פְּנִים

$\|q\| < \|p\|$  וְאֶלְגָּרָה, מְגֻחָה



replay 323 n/a surf

input  $\sim \sim \sim$

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

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

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

$\Leftrightarrow$

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

$$z^n = \pm i$$

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

$$z^n = i \Leftrightarrow$$

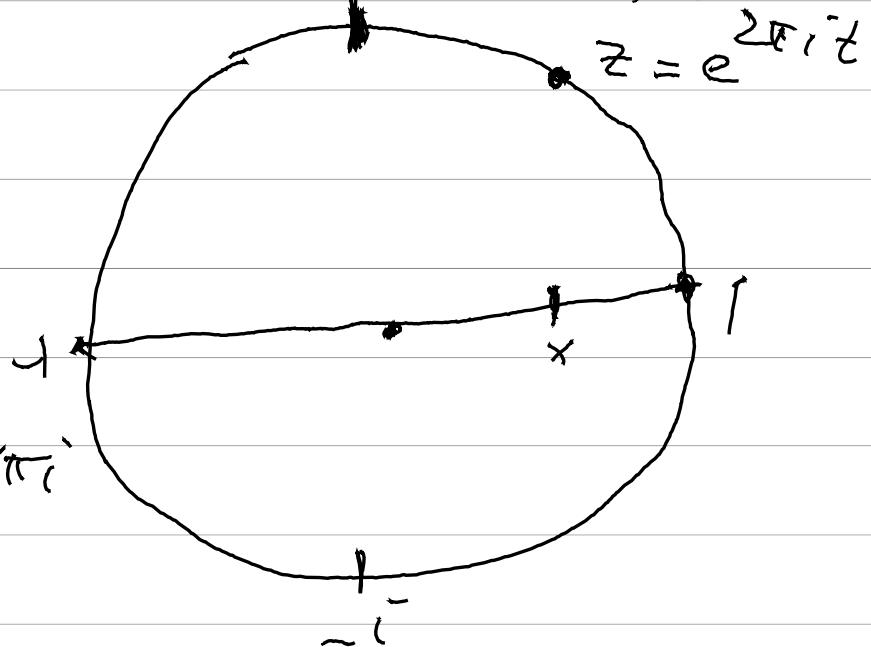
$$k=0, \dots, n$$

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

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

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

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



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

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

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

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

$a_i = \cos\left(\frac{\pi i}{n}\right)$   $\rightarrow 1/2$

Given  $x'_n = \sum_{i=1}^n a_i \cdot e_i$

for all  $n \in \mathbb{N}$  &  $\frac{1}{2} T_n$

and  $\int_0^1 x'_n \sin x dx$

$\rightarrow \lim_{n \rightarrow \infty} \int_0^1 x'_n \sin x dx = 0$

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

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

—

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

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

$\delta_i$

$P_i$

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

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

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

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

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

$c_{i+1} - c_0$

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

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

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

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

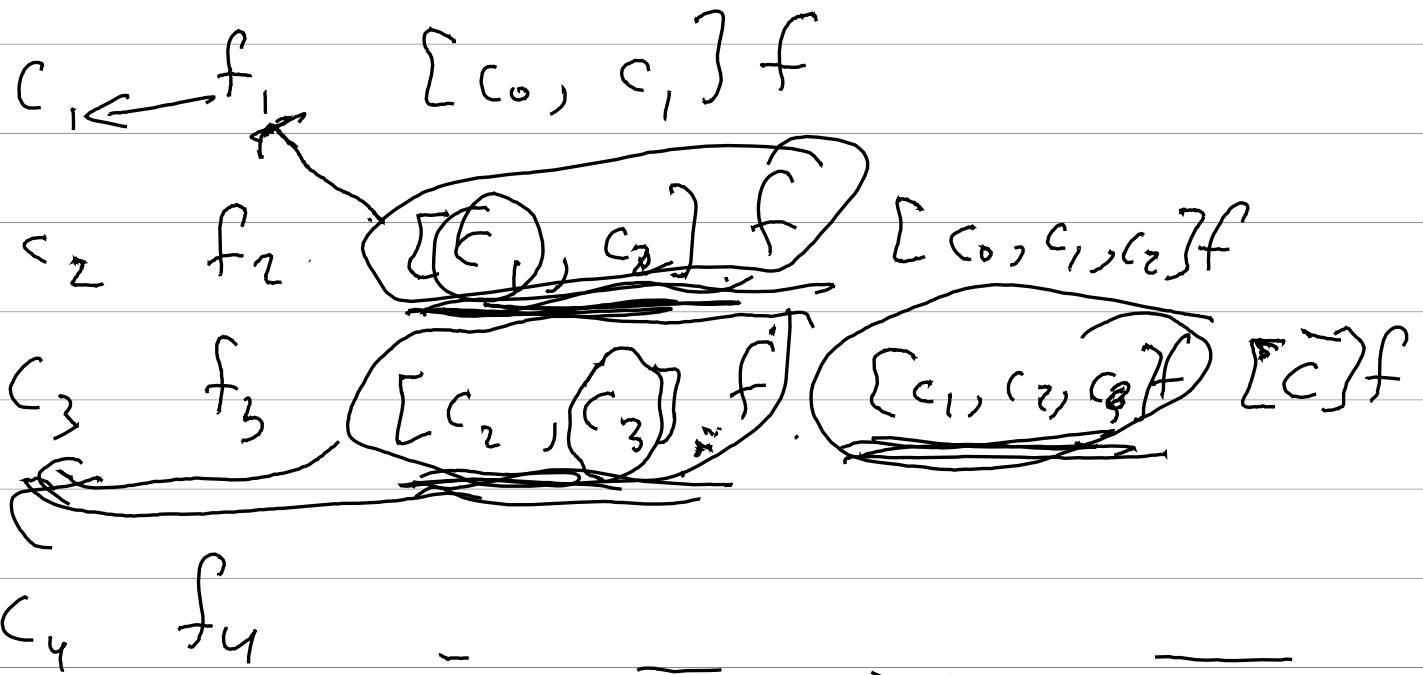
$$q(c_0) = P_{\tilde{C}_{i+1}}(c_0) = f_0 = P_{\tilde{C}}(c_0)$$

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

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

$c$        $f$

$c_0$        $f_0$



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

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

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

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

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

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

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

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

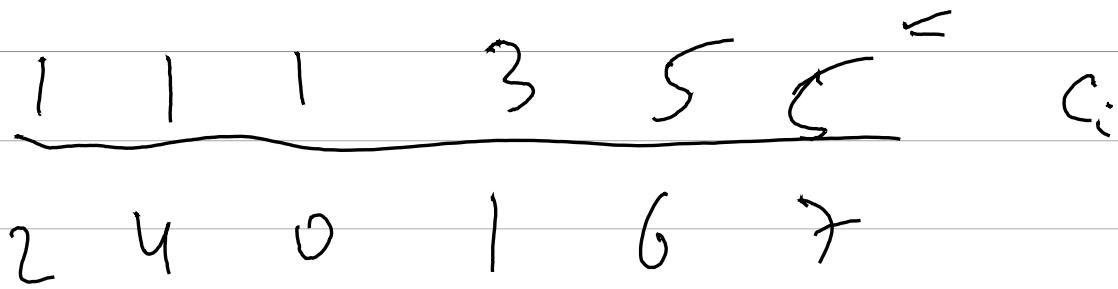
$$\hat{c}_i = \{c_0, \dots, c_n\} \setminus \{c_i\}$$

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

$c_0, \dots, c_h$

$f_0, \dots, f_n$

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\text{at } \tilde{c}_i = \frac{\tilde{d}_i f_i}{\sum_{j=1}^n \tilde{d}_j f_j}$$

$$= \lim_{\epsilon \rightarrow 0} \int_{\tilde{d}_i - \epsilon}^{\tilde{d}_i + \epsilon} f(x) dx$$

$$[(n-1)[\tilde{c}_0] + [c_0 + \epsilon]]f \rightarrow \underbrace{[n[c_0]]f}_{\epsilon \rightarrow 0}$$

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

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

$$c_0 = c_1 = c_2$$

$$c_5 = c_6$$

$$c_0 \quad f_0$$

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

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

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

$$c_4 \quad f_4$$

$$c_5 \quad f_5$$

$$c_6 \quad f_5 \quad f_6$$

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

$c_6^{11}$

$$[c_5, c_3] f$$

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

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

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

↓

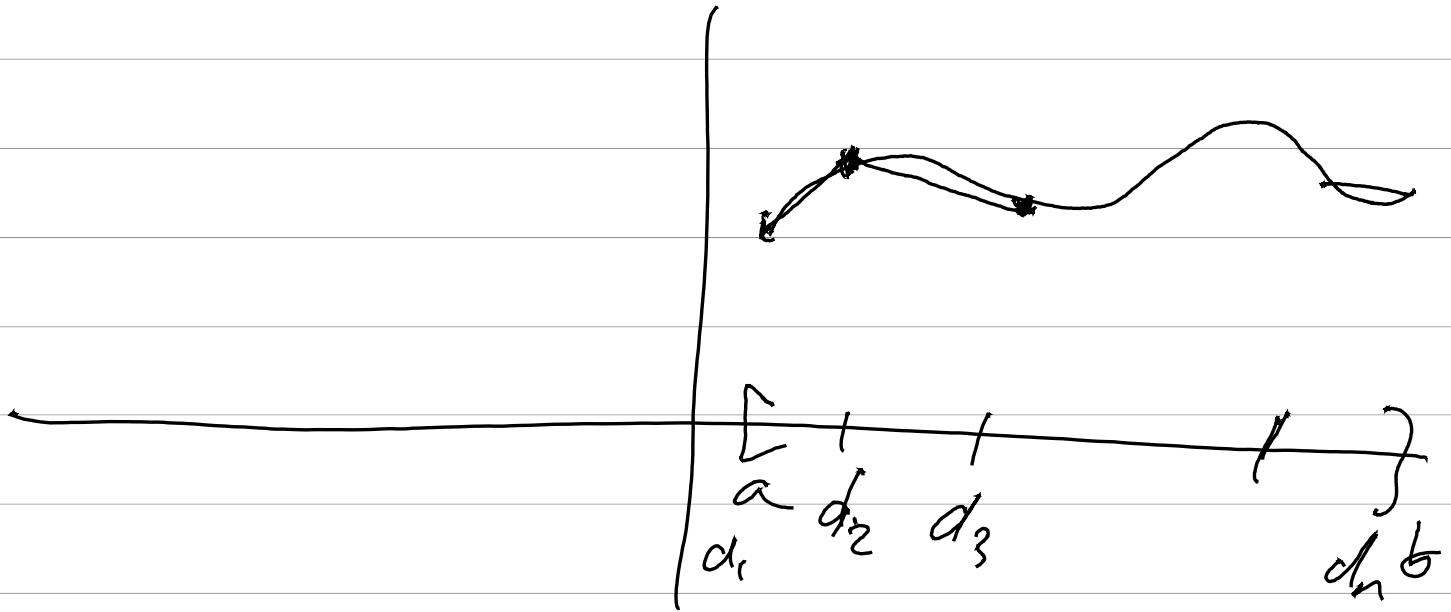
$$d_0 \quad d_1 \quad d_2 \quad \dots \quad d_n$$

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

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

$$k < m$$

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



trap > > 'sc f ~~approx~~

$f$   $\int_a^b$   $\approx$   $\text{trap}$   $\rightarrow$   $f(x)$ ,  $MV$   
 $\approx$   $\int_a^b$   $\approx$   $\sum_i f(d_i) \Delta x$

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

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

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

(a)  $\rightarrow$   $\lambda$ )  $\wedge \lambda$   $\rightarrow$   $\lambda$   $\lambda$

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

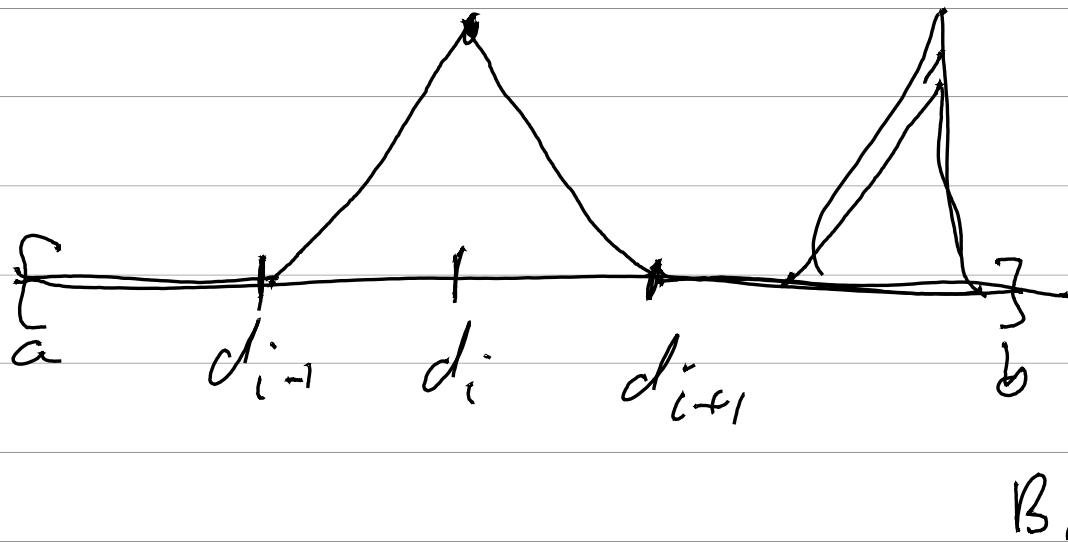
$|\Delta| =$   $\sqrt{\Delta^2 + \gamma^2}$   $\approx$   $\gamma$

$$\|f - \zeta_1\| \leq \underbrace{\|f - \zeta_0(\theta)\|}_{\text{error}}$$

$V =$   $\partial \Omega$   $\cap$   $\{x \in \mathbb{R}^n : \zeta_0(x) \leq 0\}$

$\zeta_0(x) = 0$   $\Rightarrow$   $x \in V$

$R^{d_1, \dots, d_n}$   $\mu$



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

~~$|i-j| \leq 1$~~   $\Rightarrow$

~~across~~

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

$$s \in V \quad \text{and} \quad f \in \mathcal{F}(G, \gamma)$$

Let  $\|f\|_{L^2(\gamma)}$  be the  $L^2$  norm of  $f$ .

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

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

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

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

“Wish” / “Wish”

$$\|f - \hat{g}\|_\infty \leq 4 \cdot d(f, \overline{s_1^o(\Delta)})$$

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

دلتا '3' for f the 2121

نحوه .  $S_3'(d)$   $\pi$

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

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

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

$s'(d_i) = m_i$

$m_i = \underline{\underline{f'(d_i)}} \cdot 1_c$

- $c$   $m_i$   $\rho/(n^2 \cdot 2)$

$s \in S_3^2(D)$

1)  $f$   $\rightarrow$   $\mathbb{R}$

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

2)  $f$  is  $\mathcal{C}^1$

( $f$  is  $\mathcal{C}^1$ )  $[a, b]$

3)  $f'(x_0) = 0$

$f'(x_0) = 0$

4)  $f(x) = c$

( $f(x) = c$ )  $\Rightarrow$

$F(t, x, x', x'') = 0$  ?

$x(1) = x_1$ ,  $x(0) = t_0$

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

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

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

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

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

$\{a, c\} \cup \{c, b\}$   $\checkmark$   $\forall c \in \mathbb{R}$

$\exists c \in ]a, b[$

$f(c) \geq 0$   
 $\leq 0$

$X_n - a \in \mathbb{Q}$   $\checkmark$   $\forall c \in \mathbb{R}$   
 $c \in \mathbb{R}$   $\exists c' \in \mathbb{Q}$   $\frac{e_{n+1}}{e_n} \rightarrow c$   $\checkmark$   $\forall c \in \mathbb{R}$

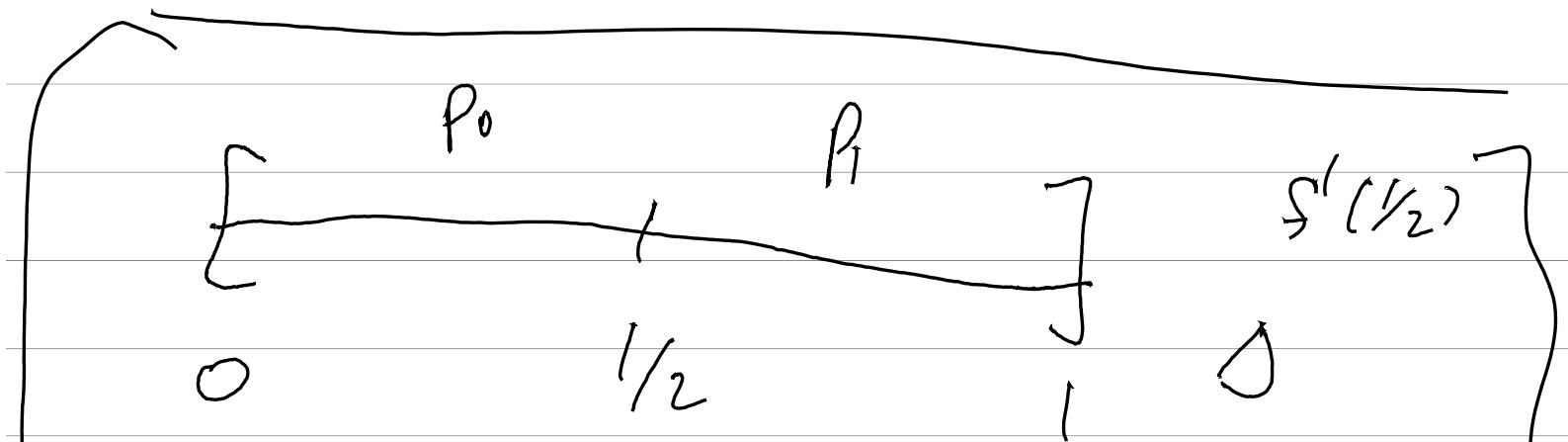
$$|x_n - a| \leq \frac{(b-a)}{2^n} = \varepsilon_n$$

→  $\rho \approx 2$

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

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

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



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

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

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

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

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

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

$$p > k$$

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

• Prenavərə

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  $0 \leq i \leq n$   $\exists$

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

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

$f_0(x), \dots, f_n(x)$  1' 3' 0' e u m g d)

1(a)-oth b.  $f_n$   $\in$   $\mathcal{M}_k$   $\forall i < n$   $\begin{cases} \text{no } \\ \text{if } \end{cases}$

ר $\in$   $\{a, b\}$   $\Rightarrow$   $f(x) = \underbrace{\sqrt{x}}$

ר $\in$   $\{c, d\}$   $\Rightarrow$   $[c, d] \rightarrow [a, b]$

$[a, b] \rightarrow$  ר $\in$   $\{c, d\}$   $\Rightarrow$   $(c, d)$

ר $\in$   $\{a, b\}$   $\Rightarrow$   $\sqrt{x}$  ר $\in$   $\{c, d\}$

ר $\in$   $\{c, d\}$   $\Rightarrow$   $\sqrt{x}$  ר $\in$   $\{a, b\}$

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

ר $\in$   $\{a, b\}$   $\Rightarrow$   $\sqrt{x}$  ר $\in$   $\{c, d\}$

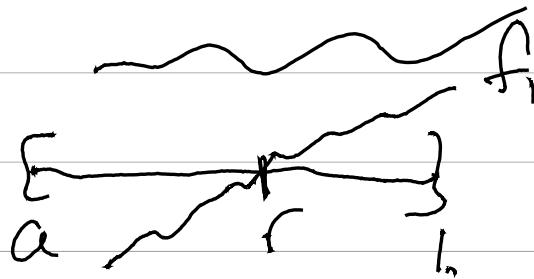
$r \in [a, b] \Rightarrow \exists x$   $f_0(r)_{x_0} = c = f(r)$

$n \in \mathbb{N}$   $\exists r \in \mathbb{Q}^+$   $\forall \epsilon > 0$   $\exists N \in \mathbb{N}$   $\forall n \geq N$

$$\checkmark n=0$$

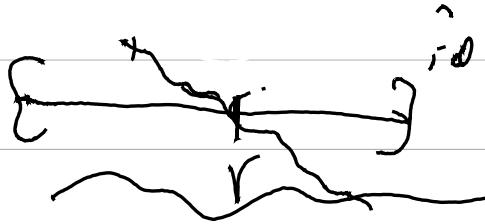
$\exists r \in \mathbb{Q}^+$   $\forall \epsilon > 0 \exists N \in \mathbb{N} : n \geq N \Rightarrow |f_n(x) - f(x)| < \epsilon$

$\rightarrow \text{AP/NH}$



$$\underline{f(a)=0}$$

$$\overline{f(b)=1}$$



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

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

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

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

: מינימום  $f'$

לפ  $x^k$  ר'ו  $f'_k(x)$  מינימום  $f_k(r) \neq 0$  . א

ר'ו  $f_1, \dots, \underline{f_{n+1}}$  ניגו,

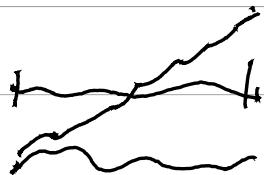
ר'ו  $f_1, \dots, f_n$ ,  $f_{n+1}$  מינימום  $f'$

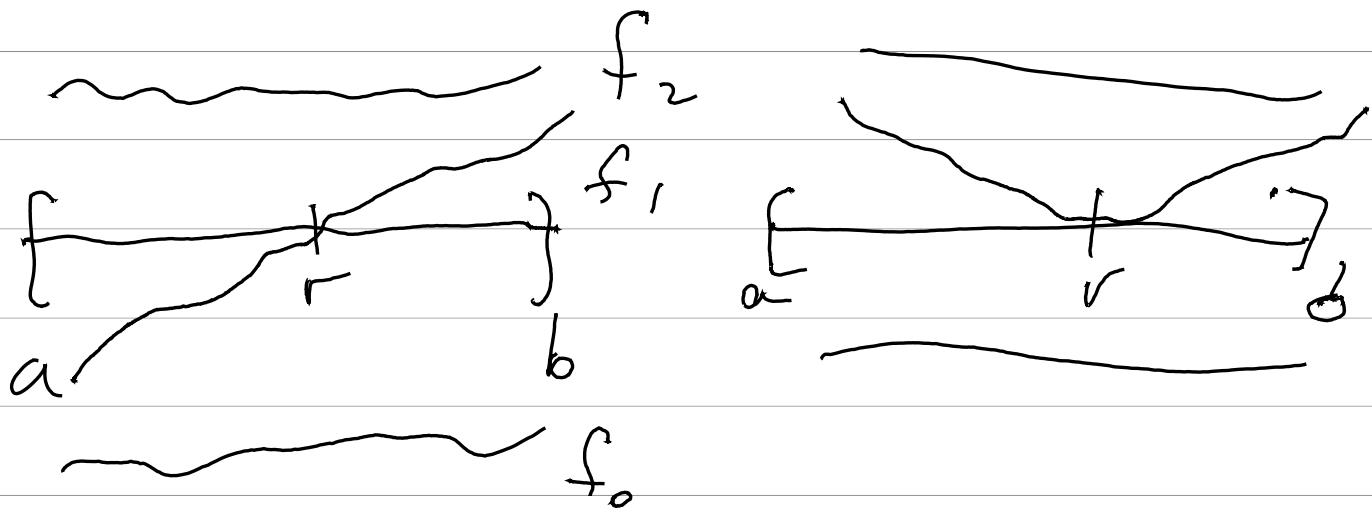
ר'ו  $f_1, \dots, f_n$ ,  $f_{n+1} = 0$

$f_0, f_1 \rightarrow$  מינימום  $f_1(r) \approx 0$  . ס

$f_0(r) \cdot f_1(r) < 0$  ניגו ס

$f_2(r) \neq 0$  ס





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

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

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

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

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

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

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  $f_i$

$\rho' / \text{JC}$

$\tau_2' / c$   $\infty \delta \delta$  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  $\exists \gamma \in \text{sm}$

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

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

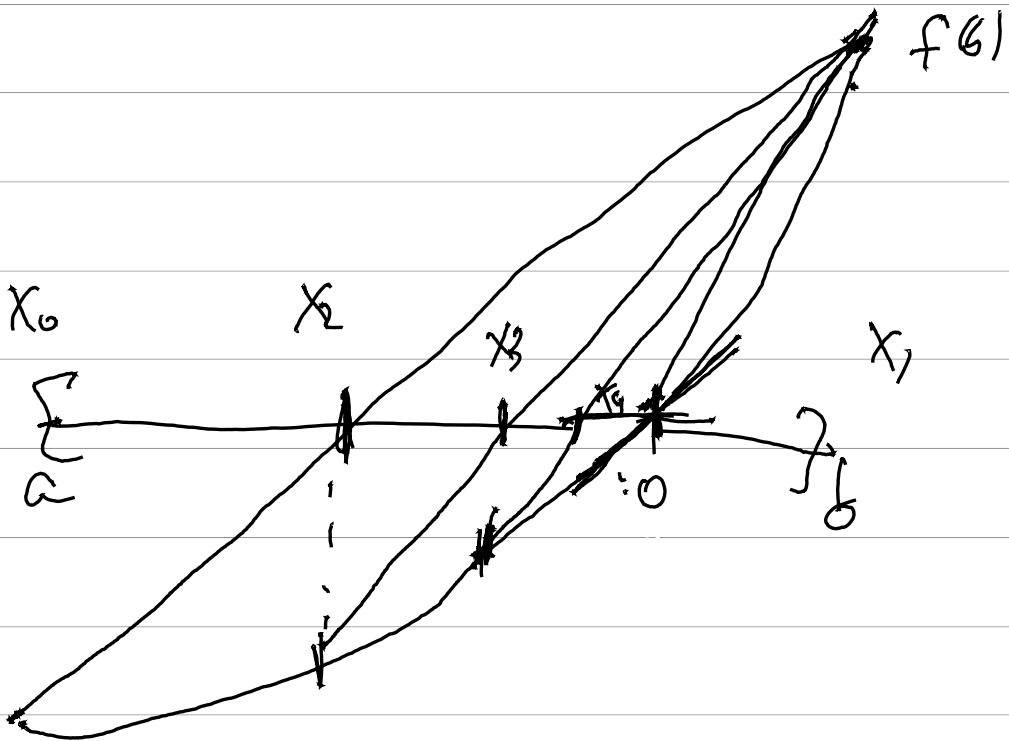


$$\frac{f(b)}{b-a}(x-a) + \frac{f(a)}{a-b}(x-b) = 0$$

$\Downarrow$

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

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



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

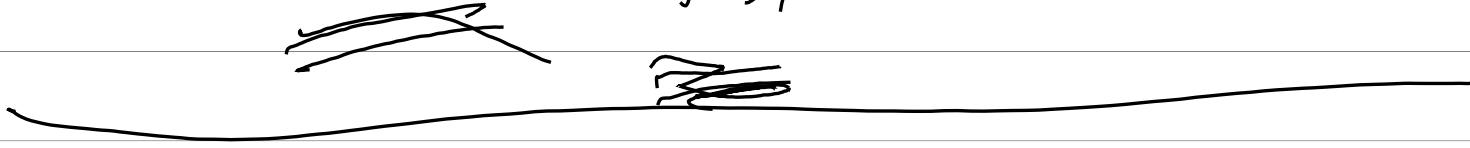
$$\frac{(f(x_n) - f(x_{n-1})) \cdot x_{n-1} + f(x_n) \cdot (x_n - x_{n-1})}{f(x_n) - f(x_{n-1})}$$

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

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

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

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



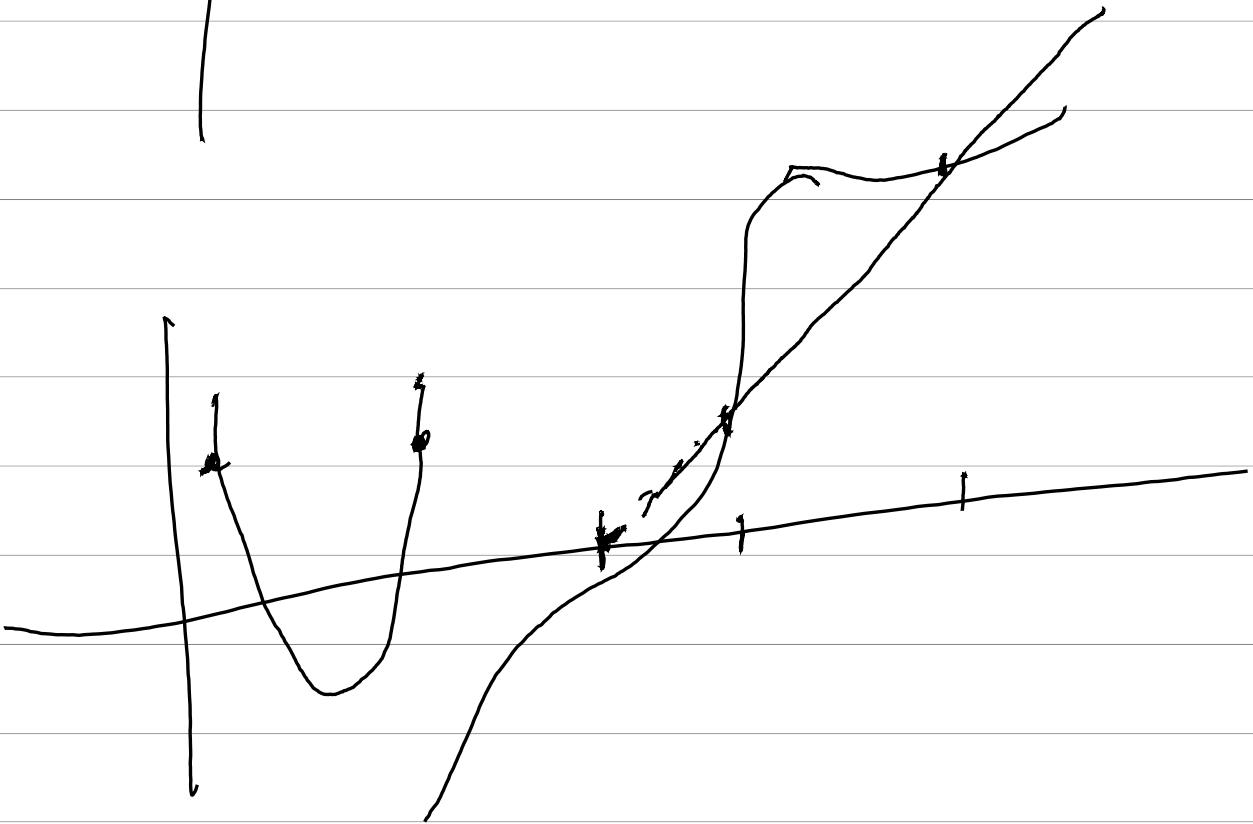
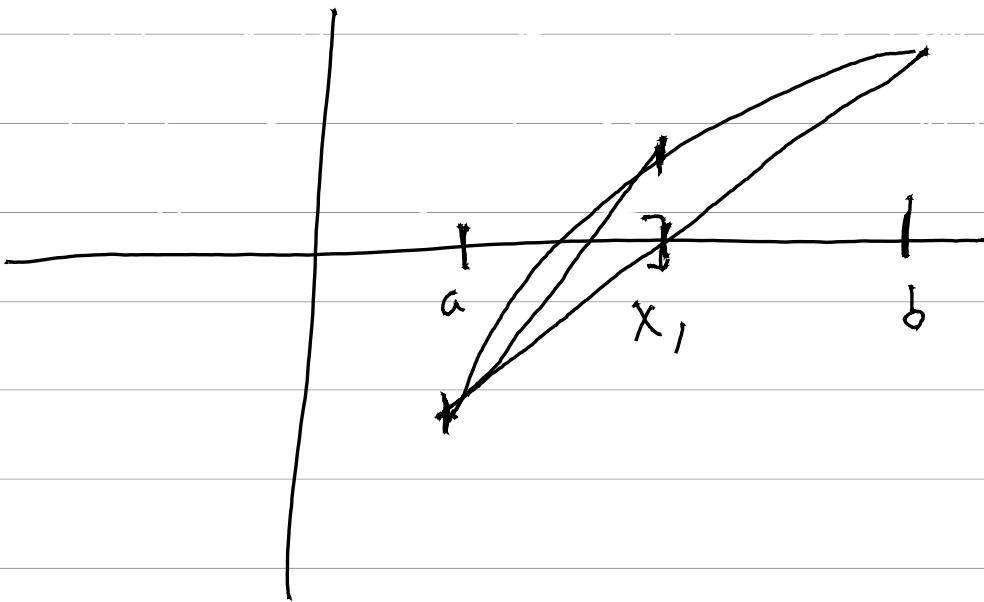
?  $\subset \mathbb{N}$ ,  $n+1 - ? \supset \mathbb{N}$

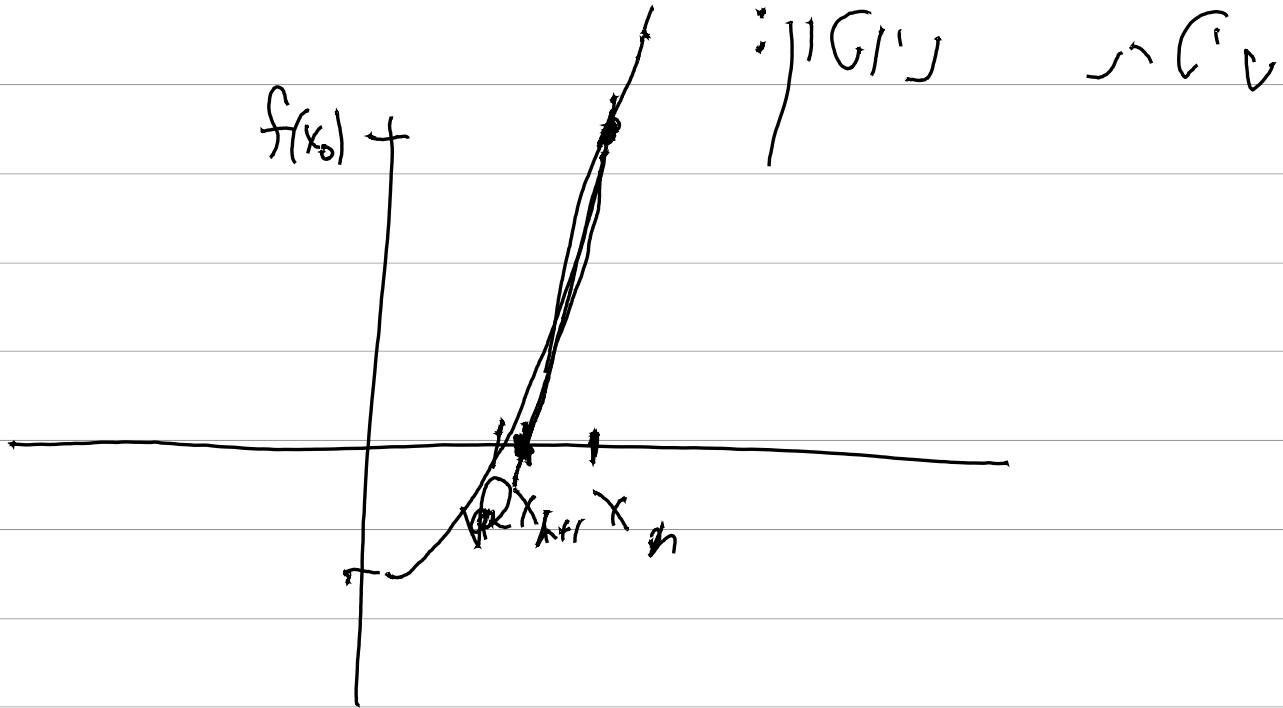
$$d = \frac{f(x_n) \cdot x_{n-1} - f(x_{n-1}) \cdot x_n}{f(x_n) - f(x_{n-1})}$$

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

Secant ->  $\cup C_1$ .1

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





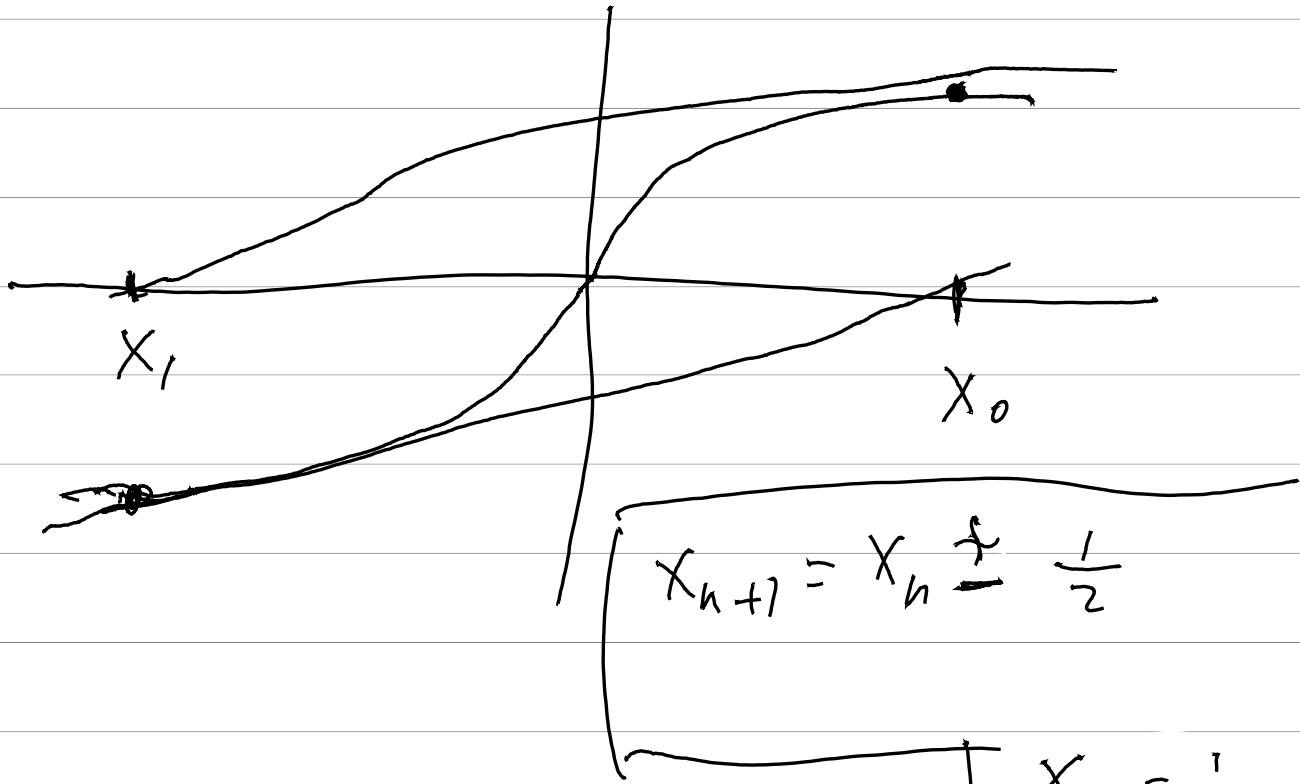
$$\left[ \frac{x_{n+1} - x_n}{0 - f(x_n)} = \frac{1}{f'(x_n)} \right] \Rightarrow$$

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

$\sqrt{a}$  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  $x, y \in M$

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

$\Rightarrow \text{Lip } X_0$

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

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

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

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

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

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

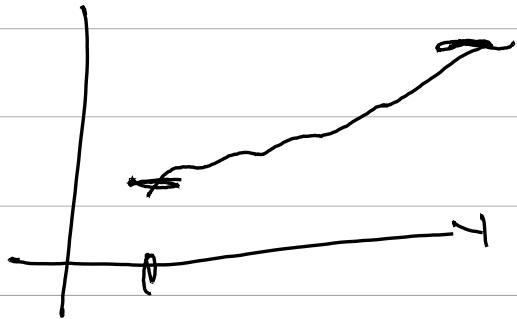
$(r^2, r^3, r^4) \subset \Delta \cup \{r\}$

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

$\text{Def}(\nu)$   
 $\nu \in \mathbb{N}^{\mathbb{N}} \quad M \subseteq \mathbb{R}$  - e  $\lambda' \cup$

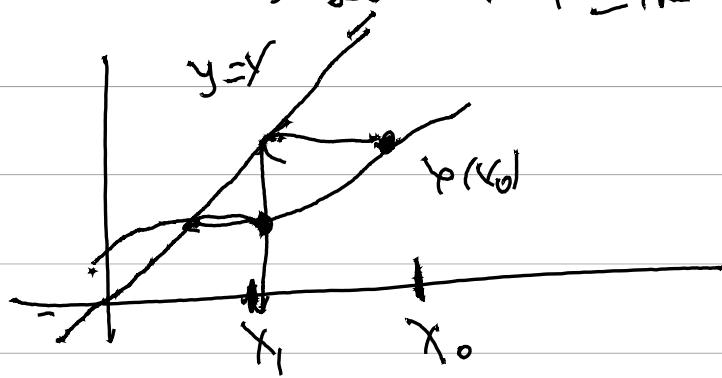
-1, No 3  $\Rightarrow$   $\lambda' \subseteq \varnothing$

all  $\nu$   $\exists c \cdot x \in M \Rightarrow \forall \epsilon < c$



Def  $\nu \in \mathbb{N}^{\mathbb{N}} \rightarrow \mathbb{R}_0 \rightarrow \mathbb{R}$

$\psi: M \rightarrow \mathbb{R}$   
such that  $M \subseteq \mathbb{R}^n$   $\rightarrow \mathbb{R}$



$\alpha^p \approx \alpha^{p+1} \approx \dots$   $\forall \epsilon > 0$

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

$$(\varphi \in C^p(M)) \cdot \underbrace{\varphi^{(p)}(\alpha) \neq 0}_{\text{---}} \quad -1$$

$\therefore p$  1.  $\alpha$  2.  $\varphi(\alpha)$  3.  $\varphi'$  4.  $\varphi''$  5.  $\varphi^{(p)}$

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

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

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

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

לעסן גראונד

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

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

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

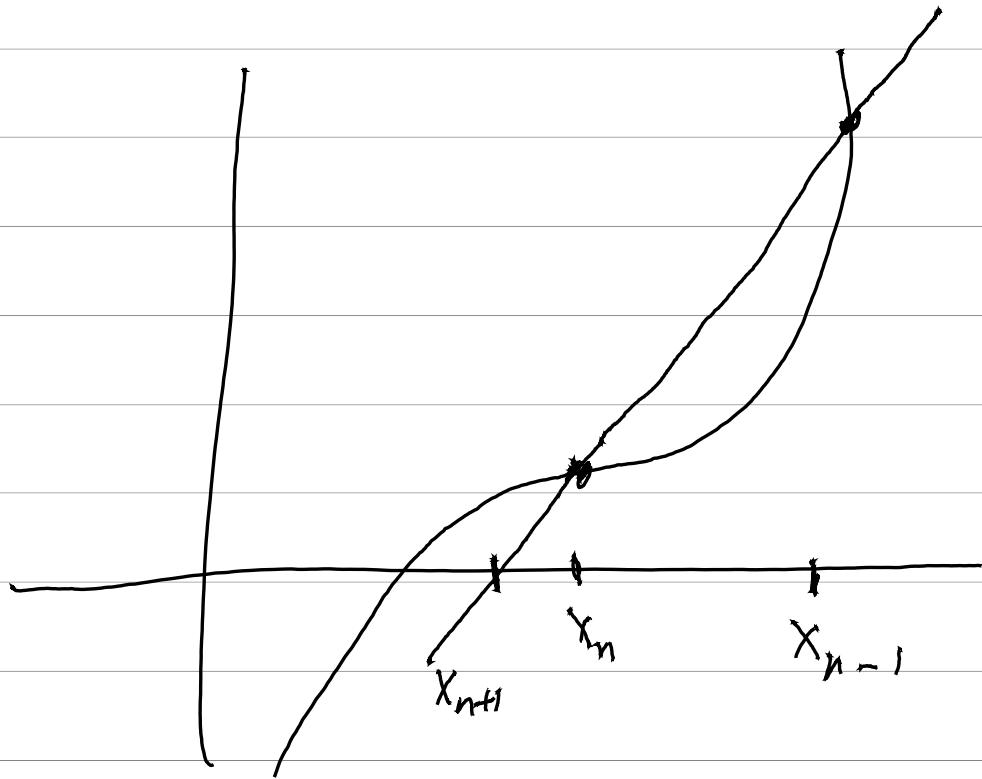
נתקה (ונרמזו) ג' 20 סכ

ב' ג' 20

$$u \text{ sod } \varphi'(u) \leq 1 \in f'(u) \neq 0$$

ולא נרמזו ב' ג' 20

Secant  $\rightarrow$   $C_V$



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

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

$\alpha$  (red) en  $\ell'$  e  $\wedge \vee$

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

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

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

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

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

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

$$M = \max_{t, s \in J} \left| \frac{f''(s)}{2f'(t)} \right| \rightarrow R_{f, J}$$

$\approx$  ?  $\approx$   $\log$   $f'$   $f'(\alpha) \neq 0$

$\approx 0$   $|f'| \approx 0$   $\approx 0$   $\approx 0$

$$\underline{U}_\alpha = \{x \mid |x - \alpha| \leq \varepsilon\} \quad \text{per sc}$$

$$\underbrace{\varepsilon \cdot M \leq 1}_{\Rightarrow} \quad \underbrace{x_{n-1}, x_n}_{\in U_\alpha} \in U_\alpha$$

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

$x_n \rightarrow \alpha \Rightarrow \approx 0 \Rightarrow n/\sqrt{n}$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\therefore r^{\prime} N \cup S \rightarrow \int \parallel C's \quad \text{sum}$$

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

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

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

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

3) 2. C.J.'s

$$f'(c_0)$$

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

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

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

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

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

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

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

$$h^n \rightarrow \underbrace{\approx c}_{\text{near zero}}$$

$$c_1 = c_0 + h \ , \ c_0 \rightarrow \underbrace{\approx c_0}_{\text{near zero}}$$

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

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

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

$$h = c_1 - c_0$$

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

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

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

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

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

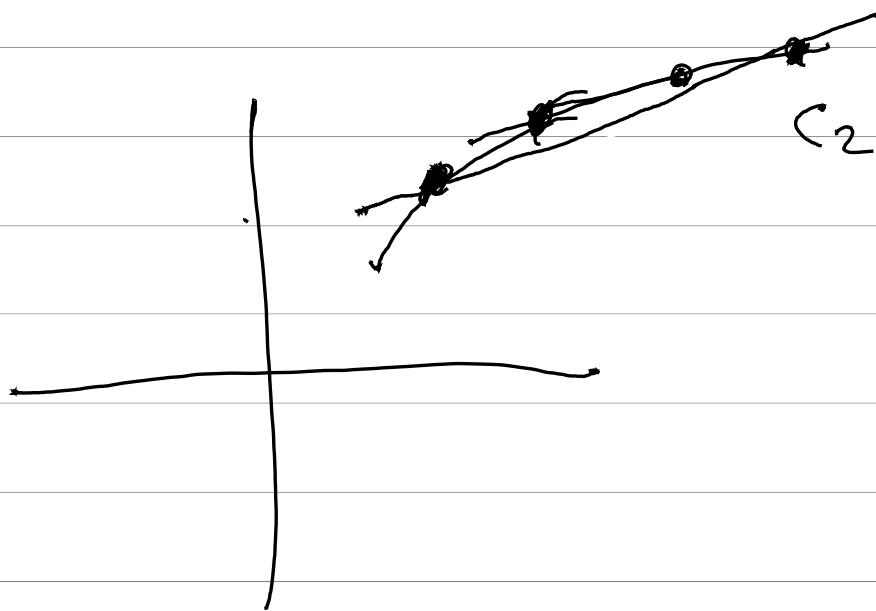
$$f(c_1) - f(c_0) + [f(c_{-1}) - f(c_0)]$$

$$\underbrace{-\frac{2}{2h^2}}_{=}$$

$$\left[ \frac{f(c_1) - 2f(c_0) + f(c_{-1})}{2h^2} \right] P = \frac{f(c_1) - f(c_0)}{h} - \frac{f(c_0) - 2f(c_0) + f(c_{-1})}{2h} =$$

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

2 h



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

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

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

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

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

Ein Messfehler

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

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

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

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



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

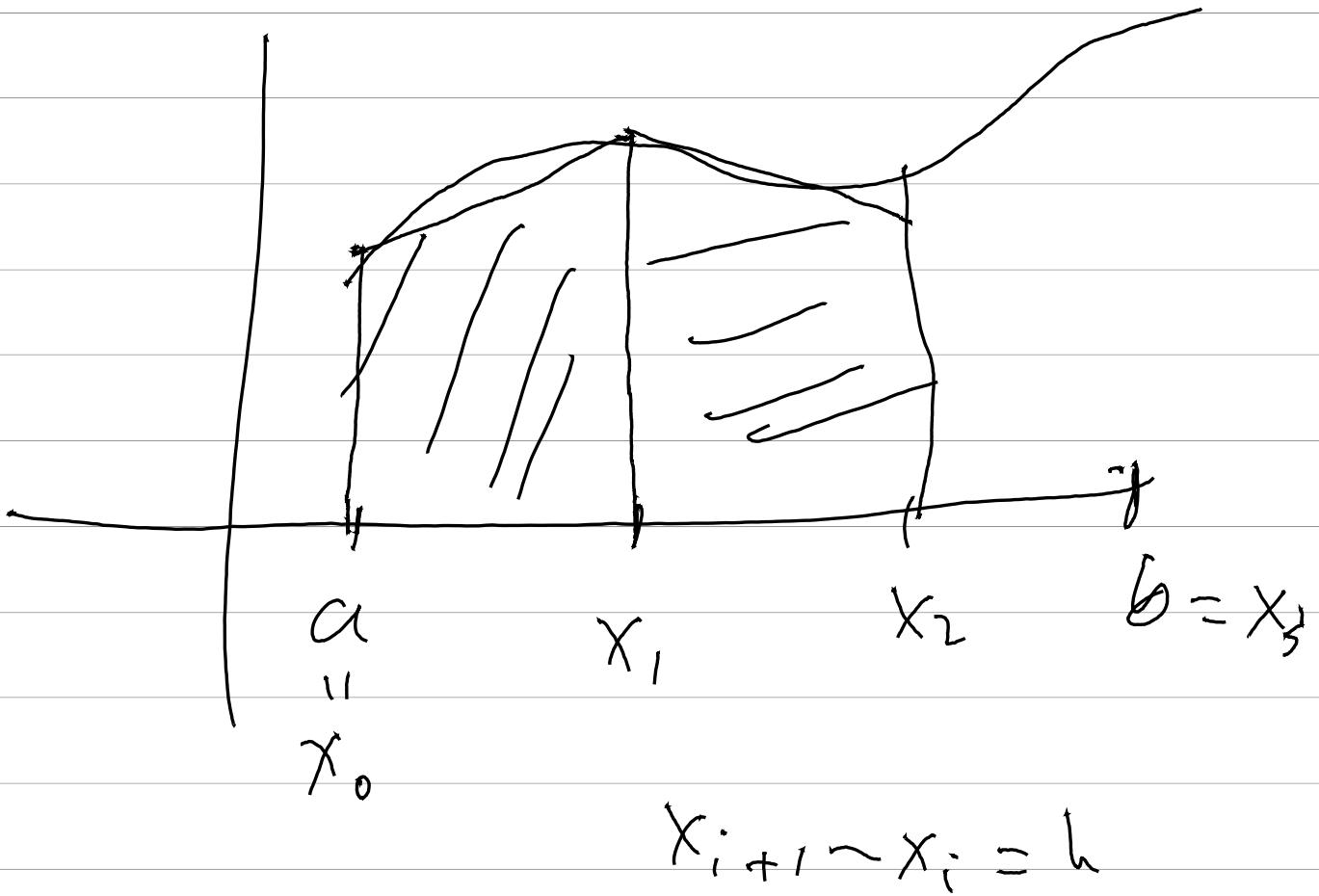
so it pers  $\approx 3 \gamma$

$$\int_a^b f$$

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

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

$\approx \int_a^b$



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

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

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

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

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

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

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

Numerical Integration

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

$x_{i+2}$

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

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

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

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

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

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



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

$$= 0 \quad k < n$$

結論  $\rightarrow f \in C$

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

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

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

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

$$\underbrace{\int_{\text{mod } 0} f(x) dx}_{\approx a_i(f)} \leq c$$

$i^{-r} / n^{\gamma}$



redukten, '55 18/12

fixen für  $\gamma'$  ist  $\gamma' > \gamma$  für  $\gamma'$

$\lambda \circ \beta \gamma$

b

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

$A =$

$$\begin{matrix} 1 & 3 & 5 \\ X & S \end{matrix}$$

$A_1, A_{-1}$

?

$T: A \rightarrow A$

$$T(f) = f \circ c \quad A_+$$

$\sqrt{\frac{m}{n}} = 1$

$$T^2 = Id$$

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

$T$  の像の定義

$A_i =$   $i$  次元空間

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

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

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

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

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

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

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

: w(t) . t<sub>i</sub> ~ s(t)

m \geq n \text{ ו } \int\_a^b f(t) w(t) dt = 0

. ר' ג'ס m ר'ג'ס

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

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

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.

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

( $\rightarrow$  3D analogic of  $\delta f$ ) for  $\delta f$

$$\varphi = \psi \circ S_{\tilde{t}}^{-1} \quad \text{near } S^C$$

. ( $\exists \pi' |_{\partial U(\omega)}$ )  $\Rightarrow$   $\varphi$  is  $C^1$  near  $\omega$

->  $\varphi$  is  $C^1$  near  $\omega$

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

$\psi(f) = 0$ ,  $f \in \ker \frac{d}{dt}$ ,  $\gamma^* \varphi$ ,  $C^1$ ,  
 $\exists \lambda \in \mathbb{C}_{2n} \cap \partial U(\omega)$

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

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

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

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

$\pi_n$  は  $n$  次の  $n$  次の

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

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

$\pi_n$  は  $n$  次の

$\pi_n$  は  $n$  次の  $n$  次の

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

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

$\pi_n$   $\subseteq$   $N \cap C_1$   $t_i$

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

???

$w(t_i)$

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

,  $\forall \epsilon / \exists N$

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

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

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

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

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

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

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

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

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

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

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

17. 1730  $\wedge$  17. 1730

8. 1730  $\wedge$   $P_n$   $\sim$  1730

$V_k \subseteq V_{k+1}$   $\wedge$  1730

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

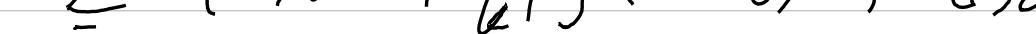
$\psi: V \rightarrow \mathbb{R}$

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

$E = \psi - \theta$

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

$f \in C^1((0, 5], \mathbb{R})$

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


$$E(f) = \frac{1}{k!} E \int_0^t \underbrace{(x-t)^k}_{=} f^{(k+1)}(\epsilon) d\epsilon =$$

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

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

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

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

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

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

# Numerical Linear Algebra

Folkmar Bornemann

A linear system of equations

$$Ax = b$$

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

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

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

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

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

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

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

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

$$A = L \cup =$$

$n \rightarrow$

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

$$X = \underbrace{\alpha_1}_{\neq 0} \quad \left| \begin{array}{c} 1 \\ 0 \\ \vdots \\ r_1 \\ U' \end{array} \right.$$

$$l_1 = \underbrace{b_1}_{\alpha_1}$$

$$B = L' \cup' \quad \text{and} \quad \begin{matrix} \alpha_1 & \alpha_2 & \dots & \alpha_n \\ b_1 & b_2 & \dots & b_n \end{matrix} \quad \text{and} \quad \begin{matrix} r_1 \\ U' \end{matrix}$$

$$B = D^1 - l_1 r_1$$

23. Find  $\lambda^3 \text{adj } A$ , if  $A = \begin{pmatrix} 1 & 2 & 3 \\ 2 & 1 & 3 \\ 3 & 3 & 1 \end{pmatrix}$

$$-1 \quad \} \Rightarrow P$$

$$PA = LU$$

Find the row U such that

1. All off-diagonal entries in  
each row  $|x| \leq 1$  are positive for

$$L \rightarrow x \rightarrow \text{Gauss Elim}$$

$$\begin{pmatrix} 0 & 1 & 2 \\ 3 & 0 & 1 \\ 5 & 1 & 2 \end{pmatrix} = P_1 \cdot \begin{pmatrix} 5 & 0 & 3 \\ 3 & 0 & 1 \\ 0 & 1 & 2 \end{pmatrix} =$$

$$P_1 \begin{pmatrix} 1 & 0 & 0 \\ 3/5 & 0 & 1 \\ 0 & 1 & 2 \end{pmatrix} \begin{pmatrix} 5 & 0 & 3 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{pmatrix}$$

$$B = \begin{pmatrix} 0 & 1 \\ 1 & 2 \end{pmatrix} - \begin{pmatrix} 0 & 3/5 \\ 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & -4/5 \\ 1 & 2 \end{pmatrix}$$

$$\begin{pmatrix} 0 & -\gamma/\varepsilon \\ 1 & 2 \end{pmatrix} = P_2 \begin{pmatrix} 1 & 2 \\ 0 & -\gamma/\varepsilon \end{pmatrix}$$

$$P_1 \cdot \begin{pmatrix} 1 & 0 & 0 \\ 0 & P_2 \end{pmatrix}$$

$\overset{11}{P}$

$$A = \begin{pmatrix} \varepsilon & 1 \\ 0 & 0 \end{pmatrix} \quad 0 < \varepsilon$$

$| \Gamma \rangle$

$$= \begin{pmatrix} 0 & 1 \\ 1/\varepsilon & 1 \end{pmatrix} \underbrace{\begin{pmatrix} \varepsilon & 1 \\ 0 & 1 - 1/\varepsilon \end{pmatrix}}_{\sim} \sim$$

$$\begin{pmatrix} 1 & 0 \\ 1/\varepsilon & 1 \end{pmatrix} \begin{pmatrix} \varepsilon & 1 \\ 0 & 1 - 1/\varepsilon \end{pmatrix} = \begin{pmatrix} \varepsilon & 1 \\ 1 & 0 \end{pmatrix}$$

Cholesky

1.5

:  $\lambda^* \lambda^* \lambda / A = A^* - c$   $\lambda^* \lambda \lambda$

$\bar{x}^* A \bar{x} > 0$ ,  $\bar{x} \neq 0$  Es

$(\bar{x}^* A \bar{x})^* = x^* A^* \bar{x} = x^* A \bar{x} \in \mathbb{R}$   $\text{s/c } A = A^* \text{ s/c}$

$(\bar{x}, \bar{y}) \mapsto \bar{x}^* A \bar{y}$   $\text{s/c } A \text{ s/c}$

$\therefore \bar{x}^* \bar{y} = \bar{y}^* \bar{x}$

$\Rightarrow N \text{ s/c } A \text{ s/c } \bar{A} \text{ s/c}$   
 $\therefore \bar{A}^* A = I_n$   $\text{s/c}$

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, 13<sup>th</sup> 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 ינטְגָרְטָה

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  $Q : \mathcal{J}' \cap \mathcal{C} \cap \mathcal{S}_C \rightarrow \mathcal{B}'$

Wieder  $Q : \mathcal{J}' \cap \mathcal{C} \cap \mathcal{S}_C \rightarrow \mathcal{B}'$

Wieder  $Q : \mathcal{J}' \cap \mathcal{C} \cap \mathcal{S}_C \rightarrow \mathcal{B}'$

$$A = Q \cdot R \Leftrightarrow \underbrace{A \cdot R^{-1}}_{\sim} = Q$$

$$R^{-1} = \begin{pmatrix} \alpha & \beta & \dots \\ r & \dots & \dots \end{pmatrix}, \quad A = (a_1, \dots, a_n)$$

$$\alpha = \frac{1}{\|a_1\|}, \quad \beta = a_1 + \gamma a_2$$

$$A = (a_1, \dots, a_n)$$

$\hat{A} = Q \cdot R = \underbrace{\underline{\underline{Q}}}_{Q_1 \cdot R_1 + (Q_2, \dots, Q_n) R^1}$

$$Q = (q_1, \dots, q_n)$$

$$A = QR$$

$$R = \begin{pmatrix} \rho & \bar{r} \\ 0 & R' \end{pmatrix}$$

$$Q^T A = R$$

$$(a_1, \dots, a_n) = (q_1, \dots, q_n) \cdot$$

$$\rho \cdot q_1 = a_1 \Rightarrow \rho = \|a_1\|, \underline{\underline{q_1 = a_1 / \rho}}$$

$$q_1 \cdot a_i \leq r_i \quad Q \cdot A = (\rho, \bar{r})$$

$$\therefore \exists g \in Q^T \cap \{x \in \mathbb{R}^n \mid Qx = 0\}$$

$$A - q \cdot r_i = Q^T \cdot R^1$$

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\*

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

$$\frac{\|A^{-1}b^* - A^{-1}b\|}{\|A^{-1}b\|} = \frac{\|A^{-1}(b^* - b)\|}{\|A^{-1}b\|} \leq \frac{\|A^{-1}\| \|b^* - b\|}{\|A^{-1}b\|} =$$

$$\frac{\|A^{-1}\| \cdot \|b\|}{\|A^{-1}b\|} \cdot \frac{\|b^* - b\|}{\|b\|} = \frac{\|A^{-1}\| \cdot \|(A + A^{-1})b\|}{\|A^{-1}b\|} \cdot \frac{\|b^* - b\|}{\|b\|} \leq$$

$$\leq \kappa(A) \cdot \frac{\|b^* - b\|}{\|b\|}$$

$$\|Av\| \leq \|A\| \cdot \|v\|$$

$$\|A\| = \sup_{v \neq 0} \frac{\|Av\|}{\|v\|} = \sup_{v \in C} \|Av\|$$

$A \in \mathbb{R}^{n \times n}$

$$\frac{\|\tilde{A}^{-1}b - \tilde{A}'^{-1}b\|}{\|\tilde{A}'^{-1}b\|} = \frac{\|\tilde{A}' \cdot \tilde{A} \tilde{A}'^{-1}b - \tilde{A}' \cdot \tilde{A} \tilde{A}'^{-1}b\|}{\|\tilde{A}'^{-1}b\|} =$$

$$\frac{\|A'(\tilde{A} - A)\tilde{A}'^{-1}b\|}{\|\tilde{A}'^{-1}b\|} \leq \|A'\| \|A - \tilde{A}\| \|\tilde{A}'^{-1}b\|$$

$$\frac{\|A'\| \cdot \|A\| \cdot \|\tilde{A} - A\|}{\|A\|} = \kappa(A) \cdot \frac{\|\tilde{A} - A\|}{\|A\|}$$

$$\|ABv\| \leq \|A\| \|Bv\| \leq \|b\| \|B\| \|v\|$$

: (Kahan) DVC

$$\frac{1}{\kappa(A)} = \min \left\{ \frac{\|A - \tilde{A}\|}{\|A\|} \mid \begin{array}{l} \text{for } \tilde{A} \\ \text{such that} \end{array} \right\}$$

, the if  $\tilde{A}$  has

$$\frac{\|A - \tilde{A}\|}{\|A\|} \geq \frac{1}{\|A\| \cdot \|\tilde{A}^{-1}\|}$$

$\rightarrow \sqrt{3} \approx 1.73$

$$\|\tilde{A}^{-1}\| \cdot \|A - \tilde{A}\| \geq 1$$

$\delta \omega / \zeta$

$$\|A^{-1}\| \cdot \|A - \tilde{A}\| \geq \|A^{-1}(A - \tilde{A})\| =$$

$$\|I - A^{-1}\tilde{A}\|$$

$$\sim c \quad \sqrt{\text{cond}} \quad | \text{down set}$$

$$\|I - A^{-1}\tilde{A}\| \geq 1$$

$\exists c \quad 0 \neq v \in \ker(A) \subset \mathbb{R}^n$

$$\|I - A^{-1}\tilde{A}\| \geq \|(I - A^{-1}\tilde{A})v\| / \|v\| = \frac{\|v\|}{\|\tilde{A}v\|}$$

$\Rightarrow \text{down set } \tilde{A} \quad S3 \quad 4$

$$\|A - \tilde{A}\| = \frac{1}{\|A^{-1}\|}$$

$$w = A^{-1}v, \|A^{-1}v\| = \|A^{-1}\| \quad \begin{matrix} \sim c \\ -1 \end{matrix} \quad \begin{matrix} \Rightarrow \\ \|v\|=1 \end{matrix} \quad \begin{matrix} \checkmark \\ 1 \end{matrix}$$

per sen V dann nur mehr J

$$\tilde{A} w = 0 \quad \gamma' \beta \beta' \omega - \delta$$

$$A|_U = A|_{U^{-1}}$$

$$\underbrace{\|A - \tilde{A}\|}_{\|w\|} \underbrace{||(\tilde{A} - A) \cdot w||}_{\|w\|} = \frac{\|v\|}{\|A^{-1}v\|}$$

$$\frac{1}{\|A^{-1}\|}$$

$$\sup_{\substack{\|cw+u\|=1 \\ u \in U}} \|(\tilde{A} - A)(cw + u)\| = \sup \|(\tilde{A} - A)cw\| =$$

$$\sup \|Aw\| / \|w\|$$

প্রার্থনা করা হৈ

মুসলিমের নির্বাচন =  $\frac{f}{f+1}$

মুসলিম -  $f$

ক' একে, য স্বত্ত্ব

~~$\hat{f}(y) = f(y^*)$~~

-c

$y^*$   
(য স্বত্ত্ব)

মুসলিম, জন এবং প্রার্থনা

cond(f)(y) নির্বাচন দ্বারা নির্ভুল

প্রেরণ সম্ভব নির্ভুল

$a^* \cdot b = a^* \cdot b$  সেন্ট নির্বাচন

•  $\lambda \circ f \circ g$  :  $\mathbb{R}^n \rightarrow \mathbb{R}^m$  injektiv

$\gamma \Gamma \vdash P \quad \exists' x \in C \quad \lambda b \rightarrow v$

$\frac{\gamma \vdash x' z' \quad \lambda (f) r \in}{\_\_}$

$\exists' z' \exists r \in \int \lambda x \in C \quad f \circ x$

$$\begin{pmatrix} a \\ b \end{pmatrix} \hat{\cdot} (c d) = \begin{pmatrix} * & * \\ * & * \end{pmatrix} + \begin{pmatrix} a \\ b \end{pmatrix} \cdot (c d)$$

$\text{det} \neq 0$

  — — —

$$\underbrace{f = h \circ g}_{\rightarrow \cup \quad \wedge' \cup}$$

(1)  $\lambda x \vdash \exists' y \exists z \varphi(x, y, z)$

$$\begin{array}{l} \hat{f} = h \circ f \circ g \\ \hline \sqrt{f} \vdash \exists' y \exists z \varphi(x, y, z) - f \end{array}$$

$\mathcal{N}(x^*)$  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-Gaches ) Dirac

$$w(\tilde{x}) = \frac{\|b - Ax\|}{\|A\| \|x\|}$$

rn/r   
 rn/r  
 ——————  
 25% 50% 100%

$$\frac{\|x - \tilde{x}\|}{\|\tilde{x}\|} = \frac{\|\tilde{A}'b - \tilde{A}'x\|}{\|\tilde{x}\|} \leq$$

$$\|\tilde{A}^{-1}\| \cdot \frac{\|b - Ax\|}{\|\tilde{x}\|} = k(A) \cdot w(\tilde{x})$$

દ્વારા કે ઉપરાંતે એવી વિધિ,

$$f = \underline{\underline{h}} \circ \underline{\underline{g}}$$

જે

$$\underline{\underline{g(A)}} = \begin{pmatrix} \underline{\underline{m}}, \underline{\underline{N}} \end{pmatrix}, \quad m \cdot N = A$$

$$\underline{\underline{h(m, n, b)}} - \text{સાધારણ પોંગ}$$

નિચેનું  
 $\checkmark - h$

ને આવું હોય તો એવી વિધિ ફ

جذب الماء

جذب الماء

$$\frac{\|\tilde{M} \cdot \tilde{N} - M \cdot N\|}{\|M \cdot N\|} =$$

$$\frac{\|\tilde{M} \cdot \tilde{N} - M \tilde{N} + M \tilde{N} - M \cdot N\|}{\|M \cdot N\|} \leq \left( \frac{\|\tilde{M} - M\| \|\tilde{N} - N\|}{\|M\|}, \frac{\|\tilde{M}\|}{\|M\|} \right)$$

$$\|\tilde{M} - M\| \cdot \|\tilde{N}\| + \|M\| \|\tilde{N} - N\|$$

$$\frac{\|\tilde{M} - M\| \cdot \|N\| \|\tilde{N}\| + \|M\| \|\tilde{N}\| \cdot \|\tilde{N} - N\|}{\|M \cdot N\|} = 2 \cdot \frac{\|M\| \|\tilde{N}\| \|\tilde{N} - N\|}{\|M \cdot N\|}$$

ר' 3rn 'ונ' ו'נ' פ' 3/7

:  $\sqrt{3} \cdot \sqrt{2} < \sqrt{5}$

$M, N \mapsto M \cdot N$

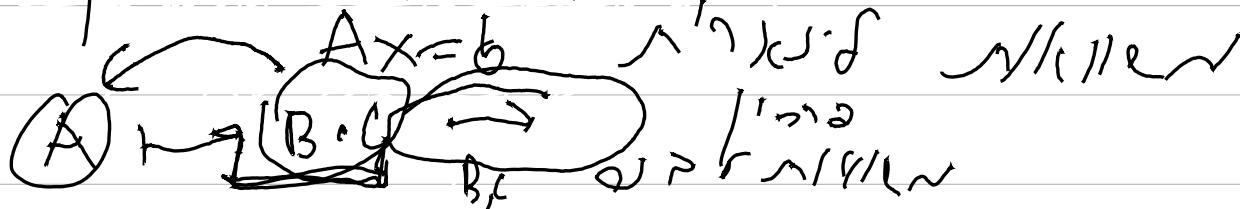
$$\frac{\|M \cdot N - M \cdot N\|}{\|M \cdot N\|} = \begin{cases} \tilde{M} = (\tilde{x} - x) + u \\ \tilde{N} = (\tilde{y} - y) + v \end{cases}$$

$$\|(\tilde{M} - M) \cdot (\tilde{N} - N)\| \leq \|M\| \cdot \|\tilde{N} - N\| + \|(\tilde{M} - M) \cdot N + M \cdot (\tilde{N} - N)\| \leq \epsilon$$

$$\frac{\|M\| \cdot \|\tilde{N} - N\|}{\|N\| \cdot \epsilon} + \frac{\|(\tilde{M} - M) \cdot N\|}{\|M\| \cdot \epsilon} \leq 2 \|M\| \cdot \|\tilde{N} - N\| \cdot \epsilon$$

$$K(M, N) = \frac{2 \|M\| \|\tilde{N} - N\|}{\|M \cdot N\|}$$

ר' 3rn 'ונ' ו'נ' פ' 3/7



reflex R  $\rightarrow$  L(C)  $\underbrace{A = Q \cdot R}_{\text{def}}$

$\rightarrow$   $\Sigma P \hookrightarrow \Sigma / (Q \rightarrow \rightarrow)$

$\|QR\| = \|R\| \in \Sigma \Sigma P \hookrightarrow / (Q$

$(L_2 \cup N_1) \cup$

$\|QRv\| = \|Rv\|$

$\|Q\| = 1$

$\overbrace{\Sigma^1 \Sigma^1}^{\text{def}} \Sigma^1 \Sigma^1 \circ A - z$

$A = \underline{R^T} \cdot R$

$\cdot \text{def} \rightarrow \text{reflex R reflex}$

$\|A\| = \begin{matrix} \Sigma^1 \Sigma^1 \\ \Sigma^1 \Sigma^1 \end{matrix} \rightarrow$

$$\|A\| = \sqrt{\|A^T A\|} = \sqrt{\max_{\mathbf{v}} \langle \mathbf{v}, A^T A \mathbf{v} \rangle} = \sqrt{\max_{\mathbf{v}} \langle \mathbf{v}, A^T A \mathbf{v} \rangle}$$

$$R = R^T R$$

$$\|R\|^2 = \|R^T R\| = \|A\|$$

$$\|A\|^2 = \max_{\|\mathbf{v}\|=1} \langle A\mathbf{v}, A\mathbf{v} \rangle =$$

$$\max \langle A^T A v, v \rangle$$

achieve  $L$ ,  $A = L U$ .  
 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)  $\rightarrow$   $\mathbb{R}$

$$\langle v_i, v_j \rangle = \delta_{ij} \cdot \text{[c]}$$

$$\underbrace{\langle u_1, \dots, u_i \rangle}_{\rightarrow} = \underbrace{\langle v_1, \dots, v_i \rangle}_{\rightarrow}, i \in [1, n]$$

$$A = (u_1, \dots, u_n) \quad | \quad \begin{array}{l} w_1 = \langle e_1 \rangle \\ w_2 = \langle e_1, e_2 \rangle \\ w_3 = \langle e_1, e_2, e_3 \rangle \end{array}$$

NO/C

$$Q = (v_1, v_2, v_3, \dots)$$

matrix from  $\mathbb{R}^n$  to  $\mathbb{R}^m$

( $\forall 0 \leq i \leq m$   $w_i \in W$ )

$w_1 \subseteq w_2 \subseteq \dots \subseteq w_n = W$

$$A, Q : W \rightarrow U$$

$$A w_i = Q w_i \quad ; \quad \text{def}$$

$$A \sim B$$

defn  $A, B$   
 $\Rightarrow P(J)$

$$\text{def } \underbrace{A w_i = B w_i}_{\sim i}$$

$$\mathcal{S}^C \quad \underbrace{A \sim B}$$

$$\mathcal{S}'^C$$

$$\text{or to } \underbrace{A = B R}_{\sim C} \quad \mathcal{S}^C \quad \mathcal{P}^C$$

$$R w_i = w_i \quad \text{def } R : W \rightarrow U$$

$$R = \underline{B^{-1} A}$$

$$\boxed{A = Q R \Rightarrow \overline{Q} = \underline{A R^{-1}}}$$

$$U_i \mapsto U_i / \mu_{U_i, 1} \quad \left( \frac{\mu_{U_i, 1}}{\dots} \right)$$

$$Ax = b$$

→ 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

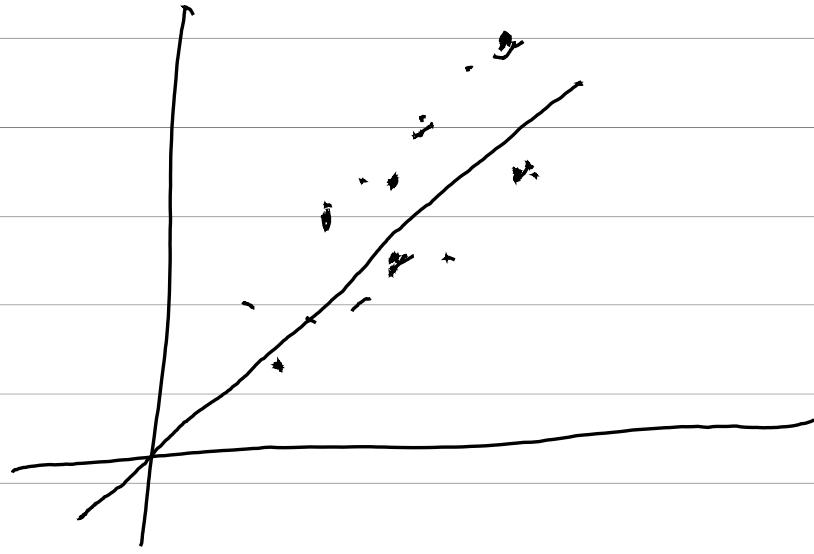
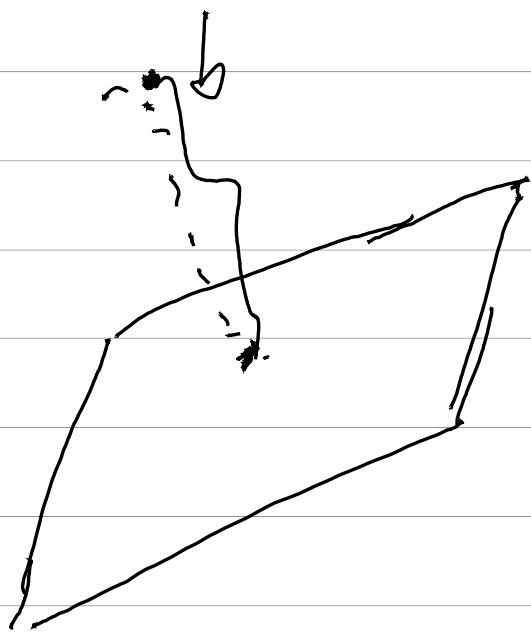
이제  $A$ 를 단위행렬  $A_x$

인 경우  $A$ 에 대한

$$-b - f \text{ 만족}$$

$$A = \underbrace{\begin{pmatrix} 1 & 1 & \dots & 1 \end{pmatrix}}_m, \quad n=1 \quad \text{인가?}$$

$$x = b_i + \underbrace{x}_{\text{new}} \quad \text{new } x$$



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$$\underbrace{A^T A}_{\text{matrix}} x = \underbrace{A^T b}_{\text{vector}}$$

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$$\kappa(A) = \|A\| \cdot \|\underline{A^{-1}}\| = \sqrt{\|A^T A\|} \cdot \sqrt{\|(A^T \cdot g)\|} =$$

$$\sqrt{\kappa(A^T A)}$$

$$A = \begin{pmatrix} 1 & 1 \\ \varepsilon & 0 \\ 0 & \varepsilon \end{pmatrix} \quad b = \begin{pmatrix} 2 \\ \varepsilon \\ \varepsilon \end{pmatrix}$$

$$Ax = b \Rightarrow x = (1, 1)$$

$$A^T A = \begin{pmatrix} 1 & \varepsilon & 0 \\ 1 & 0 & \varepsilon \\ 0 & \varepsilon & \varepsilon \end{pmatrix} \begin{pmatrix} 1 & 1 \\ \varepsilon & 0 \\ 0 & \varepsilon \end{pmatrix} =$$

$$\begin{pmatrix} 1+\varepsilon^2 & 1 \\ 1 & 1+\varepsilon^2 \end{pmatrix}$$

$$k(A^T A) = 1 + \frac{2}{\varepsilon^2}$$

$$k(A) = \frac{\sqrt{2}}{\varepsilon}$$

$\Leftarrow \|A^T A\| = \max \left( \left( \sqrt{(1+\varepsilon^2)^2 - 1} \right) \right)$

$$\begin{pmatrix} a & 1 \\ 1 & a \end{pmatrix} \quad \text{det} \quad 1+a \quad \frac{\varepsilon^2}{\varepsilon^2} \quad \frac{2+\varepsilon^2}{\varepsilon^2}$$

$$a-1 \quad \frac{1}{\varepsilon^2} \approx 1$$

$\tilde{Q}^T R x - \omega$  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

$$x + \sum a_i x^i = 0 \quad \sim \quad \begin{pmatrix} 0 & -a_n \\ 1 & -a_1 \\ 0 & \vdots \\ 1-a_n \end{pmatrix}$$

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

$$(A^T A) \quad A^T A = A^T A^T \quad \text{or}$$

$$A^T A = U \quad \text{or}$$

$$U = Q A Q^T$$

$$U^T U = Q A^T \underbrace{Q^T Q}_A Q^T = Q A^T A Q^T.$$

$$Q A^T A Q^T = \underline{\underline{U^T}} \Rightarrow$$

$$U \\ \text{N.P.O.S.C}$$

$\lambda$ ,  $\nu$   $\in A \cap \mathbb{N}$   $\forall n$   
 $\lambda > n$   
 $\nu < n$

$\lambda > n$   $\nu$   $n > \lambda$   $\nu$   $\tilde{\lambda}$

$\tilde{\lambda}$   $n > \lambda$

$|\tilde{\lambda} - \lambda|$   
~~Diagram showing two overlapping circles with a horizontal line segment between them.~~

$\|\tilde{\lambda} - \lambda\|_*$   
~~Diagram showing two overlapping circles with a horizontal line segment between them.~~

$\tilde{\lambda}$

$$\begin{aligned}
 \omega &= \min \left\{ \|\lambda - \tilde{\lambda}\| \mid \right. \\
 &\quad \left. \|(X\mathbb{I} - X^*) - (X\mathbb{I} - \lambda)\| \right\} \\
 &\quad \Downarrow \\
 &\quad \text{between } \mathbb{I} \text{ and } X\mathbb{I} - \tilde{\lambda}
 \end{aligned}$$

$$\alpha = d(\tilde{\lambda}I - A, \text{range } \tilde{A}) =$$

$$\| \tilde{\lambda}I - A \| = \underbrace{\| \tilde{\lambda}(I - A^{-1}A) \|^{\frac{1}{2}}}_{\text{rec}} = \underbrace{\| (I - A^{-1}A)^{-1} \|}_{\text{rec}} =$$

$$\text{sep}(\tilde{\lambda}, A) \left( = 0 \text{ rec } \right)$$

$$\| \tilde{\lambda} - \lambda \| = \frac{1}{\| \tilde{A} - A \|}$$

$$\| (\tilde{\lambda}I - A)^{-1} \|$$

$\mu$  'n3y p3o, 'n3y r1c1 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)  $\sqrt{1} = 1$   $\therefore A = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$

112)  $\text{HS} \rightarrow S$   $\text{HCl}$  'nby  $\text{H}_2\text{T}_2\text{O}$

•  $\exists$   $C \in A \rightarrow P' \sim \emptyset$

רְנֵנָה יְמִינָה מִזְבֵּחַ

•  $\rho' \beta \sim N(25, \sim)$

~~(x, y)~~  $\varphi_{\text{can}} \rightarrow \exists y \psi$   $\wedge \forall y$

W3Y WGP11 W3Y J3Z

Geometria - V. A. Fe

$$P(V) = \{ l \mid l \subseteq V \}$$

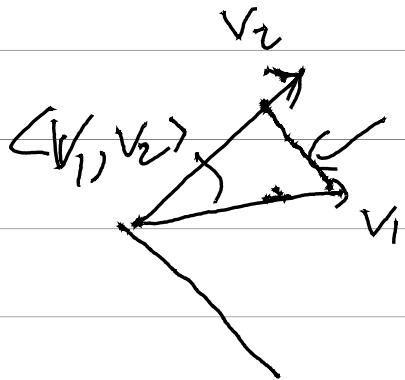
$$d(l_1, l_2)$$

7'30

Two lines intersect at a single point

$$l_1 = \langle v_1 \rangle, \quad l_2 = \langle v_2 \rangle$$

$$\|v_1\| = \|v_2\| = 1$$



$$w \in \mathbb{R}^{\perp}$$

$$\|\pi_w(v_1)\| = d(l_1, l_2)$$

$$1 = \|v_1\|^2 - \underbrace{\langle v_1, v_2 \rangle^2}_{\cos^2 \alpha}$$

$\gamma^1 \delta_N \cap A \subset \underline{\text{inv}}$

$\omega \rightarrow \text{inv}$  }  $\Rightarrow$   $\gamma^1$

$$d(\tilde{\ell}, \ell) \leq \frac{\|\tilde{A} - A\|}{\text{dist}(\tilde{\ell}, \sigma(A)\cap)}$$

$\leq$

For  $\omega$  s.t.  $\tilde{\ell}$  rec

$\cdot \lambda$   $\text{inv}$  }  $\Rightarrow$   $\tilde{A}$

$$\omega = \ell^\perp \quad \int_{\mathbb{R}^N} \text{inv}$$

,  $\tilde{v} \in \tilde{\ell}$   $\Rightarrow$   $f_n \circ \pi_w : V \rightarrow W$

$$\|\tilde{v}\| = 1$$

$$\pi_w(\tilde{A} - A) \tilde{v} = \pi_w(\tilde{X} \tilde{v} - Av) =$$

$$\pi_w(\tilde{X} \tilde{v} - A|_w \pi_w(v)) =$$

$(\tilde{X} \tilde{I} - A|_w) \pi_w(v)$

$$\pi_w(v) = (\tilde{X} \tilde{I} - A|_w)^{-1} \pi_w(\tilde{A} - A)v$$

$$d(\ell, \tilde{\ell}) = \|\pi_w(v)\| \leq \|(\tilde{X} \tilde{I} - A|_w)^{-1}\|.$$

$\|\pi_w\|, \|A - A|_w\|$

$$\underbrace{\|\pi_w\|}_{\text{sep}(\tilde{X}, D|_w)} =$$

$V = \ell \oplus W$

$$A|_\ell \subseteq \ell, \quad A|_W \subseteq W$$

$\frac{1}{\text{dist}(x, \overline{r(A)_w})}$

$r(A) - \{x\}$

רְבָרְבָרָה אֲמַרְתִּי  
בְּרוּךְ הוּא שֶׁלֹּא  
יָמַר אֶלָּתָן  
בְּרוּךְ הוּא שֶׁלֹּא  
יָמַר אֶלָּתָן

$$P(A) : P(V) \rightarrow P(V) \quad \supset \quad \{ \text{functions} \}$$

$$\underbrace{P(A)}_{\text{Probability}}(\ell) = A(\ell)$$

לעומת זה, מילויים נאמרים כפונקציית  $P(A)$  שפונקציה מ

312 ~ 75% P(A) PC

1771 14315 → 12°C 5°C

• N'3nC'c '?' & ~

(read 'n' & r) }  $\rightarrow$  l'  $\in$   $\mathcal{S}$   $\Rightarrow$   $\mathcal{S} \subseteq N$   
 $P(A)$       )<sub>C</sub>,  $\exists n \in N$  }  $\Rightarrow$   $N$

For every  $\exists \forall$   $\neg$

For  $\rho' \omega / \alpha$  there is no  $\sim$

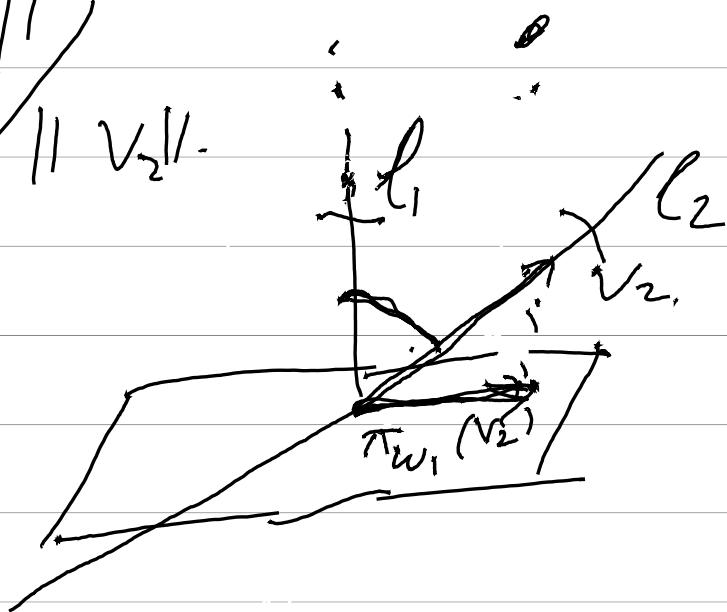
in  $\beta c \geq \lambda \sigma \sqrt{d}$

$$\left[ \sqrt{a^n + b^n + c^n} \right] \approx A^k v_0 = \frac{(x_1)}{1 \lambda_2}$$

$d(l_1, l_2) \neq v_2 \in l_2$

$$\|\pi_{w_1}(v_2)\|$$

$$\|v_2\|.$$



$$w_1 = l_1^\perp$$

$$A: V \rightarrow V$$

$$|\lambda_1| > |\lambda_2| \geq \dots \geq |\lambda_n| \quad \text{w/c}$$

$$\ell_1, \dots, \ell_n \quad \text{are eigenvectors} \quad \lambda_i$$

$$\cdot \sim |c_{\lambda}| \sim \sim \sim \sim \sim \sim$$

$$[A^* v_0] \rightarrow \ell_1, \dots, \ell_n \perp v_0$$

$$\underbrace{\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_n}_{n} \quad \ell_1 = \bigoplus_{i=2}^n \ell_i \quad \left( \frac{|\lambda_2|}{|\lambda_1|} \right)$$

$$\underline{A^* A = A A^*} \quad \therefore \text{rank } A \leq n$$

$$\text{rank } A \leq n \quad (\Rightarrow) \quad \text{rank } A \leq n$$

$$A = Q D Q^{-1} \quad \text{rank } A \leq n \quad \text{rank } Q \leq n$$

$$SC \quad A = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \underbrace{\text{basis}}$$

$$A^k \cdot \begin{pmatrix} x \\ y \end{pmatrix} = \begin{cases} \begin{pmatrix} x \\ y \end{pmatrix} & \text{if } s \neq k \\ \begin{pmatrix} x \\ -y \end{pmatrix} & \text{if } s < k \end{cases}$$

প্রদর্শন করুন। SC  $x, y \neq 0$  এর

$$[A^k \begin{pmatrix} x \\ y \end{pmatrix}]$$

অসম রেফ



বিন্দুর সংজ্ঞা বিভাগ পর

সূচিতে দেখুন কি কীভাবে

বিন্দুর সংজ্ঞা  $\|A\tilde{v} - \lambda\tilde{v}\|$  কে কো

$\lambda = \langle \tilde{v}, A\tilde{v} \rangle$

$\|v\| = 1$

" $\lambda$ "  $\lambda \gamma f(x)$   $V_0 = \sqrt{\sigma^2 f(x)}$

" $\lambda$ "  $\lambda \gamma f(x)$   $\sim \sigma f(x)$

$$\underbrace{w_{k+1}}_{\sim} = A v_k$$

$$v_{k+1} = \frac{w_{k+1}}{\|w_{k+1}\|}$$

$$\mu_{k+1} = \langle w_{k+1}, A w_{k+1} \rangle$$

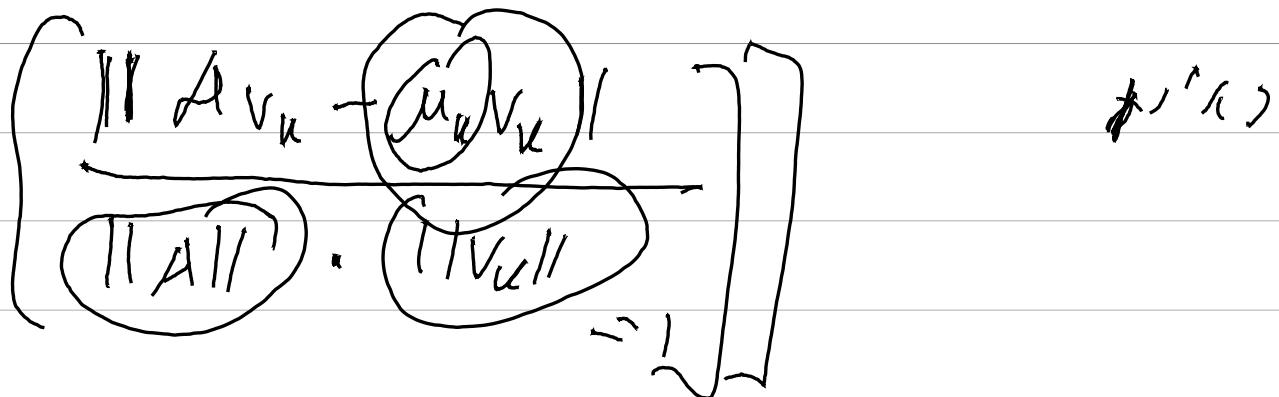
?  $\gamma$   $\gamma$   $\gamma$   $\gamma$

$\sim \lambda$   $\lambda$   $\lambda$   $\lambda$ ,  $\epsilon > 0$   $\sim \gamma \gamma \gamma$

$$\tilde{A} v_k = \mu_k v_k - e \quad \Rightarrow \quad \tilde{A} e' \\ \cdot \frac{\|A - \tilde{A}\|}{\|A\|} < \epsilon \quad \rightarrow$$

$\gamma_{\text{RC}}$   $\gamma_{\text{BDF}}$   $\sim 3/7$   $S_C$

$$\gamma > \min \left\{ \frac{\|A - \tilde{A}\|}{\|A\|} \mid \tilde{A}^T v_k = \mu_k v_{k_p} \right\} = b$$



$\gamma_{\text{RC}}$   $S_C$   $\approx 1.712$   $\approx 5$

$$\|A\|_2 \text{ and } \lambda_k$$

$$\log \left( |\lambda_1| \text{ and } \lambda_n \right)$$

Condition number  $\approx$

$$\left( \frac{\|A\|_2}{\|A\|_1} \cdot \sqrt{n} \right) \cdot \sqrt{n}$$

$A \rightarrow \delta I$   $A - \mu I$   $-f$  is eigenvector

$\lambda - 1$  probability  $\approx 1/10$

$\lambda - \mu$  rest  $A$  for 'rest'  $\rangle^{\text{rest}}$

$A - \mu I$  for  $\rangle^{\text{rest}}$

$$Av = \lambda \underbrace{v}_{(A - \mu I)v = \lambda v - \mu v =}$$

$$(\lambda - \mu) \underbrace{v}_{(A - \mu I)^{-1} v = \frac{1}{\lambda - \mu} v}$$

$$(A - \mu I)^{-1} v = \frac{1}{\lambda - \mu} v$$

1 in probability  $\approx 1/10$  chance  $\approx 1/10$

'rest'  $\rangle^{\text{rest}}$ ,  $(A - \mu I)^{-1}$



$$-c > \mu - \lambda_1 < \mu - \lambda_2 < c$$

$$|\lambda_1 - \mu| < |\lambda_2 - \mu| \leq \dots$$

then  $\sigma/\epsilon$  defines  $\sigma_{\text{eff}}/\epsilon$

$\gamma$  of  $\lambda_1 - \gamma$  is called  $\gamma$

$$(A - \mu I)^{-1} \quad \text{if } \mu \neq \lambda_i \quad \text{for } i = 1, 2, \dots, n$$

$$\text{and } \gamma = \lambda_i \quad \text{for } i = 1, 2, \dots, n$$

$$(A - \mu I) \underline{w}_k = v_k \quad \text{for } k = 1, 2, \dots, n$$

$$\frac{1}{v_k - \mu}$$

$$d_{k+1} = \langle v_{k+1}, A v_k \rangle^{-1}$$

$$v_{k+1} = \underline{w}_{k+1} / \|w_{k+1}\|^2$$

$$\cancel{(A - \mu I)} \underline{x} = \underline{b}$$

→ 2' 3' | 8 2' 8 2' → 2' 1' 1' 0' 0'

UNIC 1978 (1978) 15

151 'n' 2 2 2 2 2 2 2 2

X - i

The graph shows a positive linear correlation between the number of nodes (x-axis) and the number of edges (y-axis). The data points are approximately as follows:

Number of nodes	Number of edges
10	10
15	15
20	20
25	25
30	30
35	35
40	40
45	45
50	50
55	55
60	60
65	65
70	70
75	75
80	80
85	85
90	90
95	95
100	100

Q R non si sic

$$\begin{pmatrix} * \\ 0 & \dots & 0 \end{pmatrix} = R = Q^* A Q$$

• ↗ 1888 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  $\mathcal{N}$

$$\sim \text{in } C_{ijk} \quad Q_k \cdot / \circ$$

~~$A_k \rightarrow R \cdot \omega$~~

$$\begin{pmatrix} \cancel{*} \\ 0 & 0 & \dots & 0 & \lambda \end{pmatrix}$$

$$\rightarrow \sqrt{3} \cdot \sim R$$

$$\left( \text{in } C_{ijk} \text{, } V_0 = \ell_m \right) \quad ) \quad \underbrace{\vdots \text{ in } \mathcal{N}}_{\text{in } \mathcal{N}}$$

$$Q_k = \begin{pmatrix} \cancel{*} & | & v_k \\ \text{in } C_{ijk} & .3 & w_k \end{pmatrix} \quad v_k = \frac{w_k}{\|w_k\|} \quad \begin{matrix} \cancel{w_k} \\ \cancel{\|w_k\|} \end{matrix} \quad 2$$

$$A_{k+1} = \cancel{Q_k^T} A_k Q_k \quad 4$$

$$(A_k - \lambda_k I) = \underbrace{Q_k R_k}_{\mathcal{C}} \quad \checkmark$$

$$Q_k R_k : (A_k - \lambda_k I)^{-1} = I$$

$$Q_k^* = R_k (A_k - \lambda_k I)^{-1}$$

$$\underbrace{e_m^* Q_k^*}_{= \underbrace{e_m^* R_k}_{\mathcal{C}}} (A_k - \lambda_k I)^{-1} =$$

$$\underbrace{r_0 \cdot e_m^*}_{\mathcal{C}} (A_k - \lambda_k I)^{-1} = \underbrace{\omega_k}_{\mathcal{C}} = v_k$$

$$R_k = \begin{pmatrix} i & * & i \\ j & i & \\ & & r_0 \end{pmatrix}$$

$$A_{k+1} = Q_k^T A_k Q_k =$$

$$Q_k^T (A_k - \mu I + \mu I) Q_k =$$

$$Q_k^T (A_k - \mu_k I) Q_k + Q_k^T \mu_k Q_k =$$

$$R_k Q_k + \mu_k I$$

Algorithm

$$QR \quad \text{find } R \quad \text{and} \quad K \in \mathbb{R}^{n \times n}$$

$$A_k - \mu_k I = Q_k R_k$$

$$A_{k+1} = R_k Q_k + M_k I \quad \text{and} \quad -2$$

$$\underbrace{\begin{pmatrix} * \\ \dots \\ 0 & 0 & v_k \end{pmatrix}}_{\text{rank } k} \leftarrow A_{k+1} \quad S'k$$

$$\gamma \left| \vec{G}_j \right| \left| \vec{w}_j \right| \quad \} \rightarrow \quad \text{Jacobi}$$

$\vec{w}_j$

$$(W_{n+1} (A - \mu I) = v_n \leftarrow \underbrace{\dots}_{v_0} \quad A^{\mu} v_0$$

$$v_{n+1} = \frac{w_{n+1}}{\|w_{n+1}\|} \quad w_{n+1}$$

$$w_n (A_n - \mu_n I) = e_m$$

$$A_n - \mu_n I = Q_n R_n \Rightarrow A_{n+1} = Q_n G + K_n I$$

$$A_n \rightarrow \begin{pmatrix} * & * \\ * & * \\ \hline 0 & 0 \end{pmatrix}$$

$i \sum \mu_i = 0$ ; ( $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_n$ )

$$\boxed{A_K = Q_K R_K, A_0 = A, A_{K+1} = R_K Q_K}$$

$$(A - \mu I) = QR$$

$$Q = (A - \mu I) R^{-1}$$

$$(A - \mu I)^* = R^* Q^*$$

$$(R^*)^{-1} (A - \mu I)^* = Q^*$$

$$(A - \mu I) = Q R$$

$$I = Q R (A - \mu I)^{-1}$$

$$Q^T = R (A - \mu I)^{-1}$$

$$e_m^x Q^T = e_m^x R (A - \mu I)^{-1} =$$

$$e_m^x \cdot f (A - \mu I)^{-1} = f \cdot w_k$$

$$R = \begin{pmatrix} & \\ & f \end{pmatrix}$$

V<sub>k</sub>  
"

$$\underbrace{f}_{>0}$$

$\lambda_{\text{CC}} \approx 1.05 \int A \text{ d}A$

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?

$$A_K = S_K \underbrace{R^{-1} P^{-1} (L^{-1} D L)}_{\text{wavy line}} P R S_K^{-1}$$

$$B_K = P^{-1} D_K \underbrace{L^{-1} \underbrace{D L}_{\text{DL}} D^{-1} P}_{\text{wavy line}} =$$

$$W_K = \underbrace{P^{-1} D^K P R S_K^{-1}}_{\text{wavy line}} \Rightarrow$$

$$A_K = W_K^{-1} B_K W_K$$

$$\begin{aligned} U_K S_K &= A^k = \\ X D^k X^{-1} & \end{aligned}$$

$$W_K = P^{-1} D^K P R S_K^{-1} =$$

$$\begin{aligned} P^{-1} (D^k L^{-1} D^{-1}) \underbrace{D^k X^{-1} S_K^{-1}}_{X^{-1} S_K^{-1}} &= \\ X D^k X^{-1} & \\ X^{-1} S_K^{-1} &= D^{-1} X^{-1} U_K \end{aligned}$$

$$P^{-1} (D^k L^{-1} D^{-1}) \underbrace{X^{-1} U_K}_{\text{wavy line}} = -$$

$$P^{-1} (D^k L^{-1} D^{-1}) \underbrace{X^{-1} U_K}_{\text{wavy line}} = -$$

$\mathcal{A}' \cup \mathcal{S}_C \supseteq \mathcal{P}' \cap C_{\mathcal{V}}$   $\cap$   $\mathcal{D}$   $\supseteq \mathcal{S}_C$

$$B = \begin{pmatrix} \lambda_1 & \dots & \lambda_n \end{pmatrix}$$

$$\phi^{-1}(a_{ij}) D = \left( \star \left( \frac{\lambda_i}{\lambda_j} \right) a_{ij} \right)$$

$$\text{if } \left| \frac{\lambda_i}{\lambda_j} \right| < 1, \text{ then } \text{converges}$$

$$n \rightarrow \infty \text{ or } n \rightarrow -\infty \quad i > j$$



$$\underbrace{P^{-1} D P}_{D_\pi} = \begin{pmatrix} \tau^{\pi(1)} & & \\ & \ddots & \\ & & \tau^{\pi(n)} \end{pmatrix} \quad P = P_\pi$$

$$A_K = \omega_K^{-1} B_K \omega_K =$$

$$\omega_K^{-1} D_{\bar{\pi}} \omega_K + \omega_K^{-1} (B_K - D_{\bar{\pi}}) \nu_K$$

$\nearrow P$        $\searrow 0$

reform, each  
stage

$A_K$  be possess  $s_C$

mean  $\delta_{\bar{\pi}}$   $D_{\bar{\pi}} - \delta$  own

-0.5 own  $\mu_{0.5}, \delta_{1,0}$

Bruchat  $\rightarrow$   $\gamma_1 \gamma_2 \dots \gamma_n \gamma_1$

$$T := \begin{pmatrix} 0 & \dots & a & \dots \end{pmatrix} \quad a \neq 0 \\ \Rightarrow \exists R \\ \text{...} \\ \approx \text{...}$$

$$\overline{TR} = \begin{pmatrix} 0 & \dots & 1 & 0 & \dots \end{pmatrix} \Rightarrow L \\ \text{...} \\ \approx \text{...}$$

$$L \overline{TR} = \begin{pmatrix} 0 & \dots & i & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \\ 0 & \dots & 0 & 0 & \dots \end{pmatrix} \Rightarrow P$$

$$L \overline{TR} P = \begin{pmatrix} 0 & 0 & \dots & 0 \\ 0 & \dots & \dots & \dots \\ 0 & \dots & \dots & \dots \\ 0 & \dots & \dots & \dots \end{pmatrix} \quad T_1$$

$L, P, R$   $\in \mathbb{R}^{n \times n}$

$$T_1 = \sum_i P_i D_i \\ L \overline{TR} P = \sum_i \tilde{P}_i \tilde{D}_i$$

$$\tilde{R}_1 \quad \text{sign } P$$

$$\begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & \text{triangle} \\ 0 & 0 \\ 0 & 0 \end{pmatrix} \cdot P = P \cdot R_2$$

sign and  $R_2$

row echelon form

$\rightarrow$  always  $\neq 0$

$$A = LPU$$

L, N/A's zeros, U zero

row  $P^{-1}$  sign matrix

sign of  $P^{-1}$  sign of  $P^{-1}$

$\Rightarrow B \rightarrow \text{Graf } |'n'n A \leq \sqrt{\delta})$

$A \leq \lambda Q/nm \in \sqrt{\delta}$

$\neg \exists n \in \mathbb{N} \Rightarrow \forall \delta \exists N \in \mathbb{N} \quad B$   
'ז' סר ג' מילס פ'ג' ג'  
'א' נ' ג' א' צ'ס'

$\wedge \exists J \in \mathbb{N} \quad \forall k \geq J \quad (\exists \alpha_j)$

$\forall j \in \mathbb{N} \quad \forall k \in \mathbb{N} \quad \exists \alpha_j$   
 $\exists \beta_j \in S^* \quad \forall i \in \mathbb{N} \quad \beta_j \beta_i \in \alpha_j$

$V = \text{all } \alpha \in \text{Seq } \exists' \alpha \in \mathcal{F}_d$

$\Delta V = \left( \begin{array}{cccccc} 0 & 0 & 1 & 0 & 0 & 0 \\ \downarrow & & & & & \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array} \right) \cdot e$

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

$$A_i = L_i, P_i, U_i$$

$$\tilde{L}_i = I \oplus L_i \quad \text{JND}$$

$$\begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & & & \\ \vdots & & \tilde{L}_i & \\ 0 & & & \end{pmatrix} \Rightarrow LAUP = \tilde{L}_i, \tilde{P}_i, \tilde{U}_i \Rightarrow$$
$$LAC = \overline{\tilde{L}_i, \tilde{P}_i, \tilde{U}_i}$$

-  $\sim \tilde{U}_1 P$   $\text{libBn} \int$   $\text{reac}$   $\xrightarrow{\text{rg}}$   $G$

$$\underbrace{\tilde{U}_1 \cdot P^{-1}}_{=} = P^T U^T \quad \Rightarrow \quad P(j) = 1$$

$\text{arg} \int v \text{ dist } P$   $\xrightarrow{\text{rg}}$

$$P(i) = i+1 \quad i < j \quad \therefore 1 - \delta_{ij}$$

$$P(j) = 1 \quad P(j) = P_j e^{-\cdot}$$

$$P(i) = i \quad i > j$$

$$\tilde{U}_1 \begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & \ddots & & \\ \vdots & & \ddots & 0 \\ 0 & 0 & \dots & 0 \end{pmatrix} \Rightarrow$$

$$\tilde{U}_1 \cdot P^{-1} \xrightarrow{\text{?}} \begin{pmatrix} 0 & \dots & 0 & | & 0 & \dots & 0 \\ 0 & \dots & 0 & | & 0 & \dots & 0 \\ \vdots & & \vdots & | & \vdots & & \vdots \\ 0 & \dots & 0 & | & 0 & \dots & 0 \end{pmatrix} \Rightarrow$$

$$P \cdot \tilde{U}_1 P^{-1} = \begin{pmatrix} X & 0 & Y \\ 0 & \ddots & 0 \\ 0 & 0 & Z \end{pmatrix} \in \mathbb{M}^{3^k, 3^k}$$

•  $\sqrt{17} \approx 4.1231$

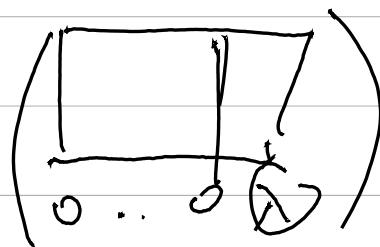
$A_k R$   $\rightarrow$   $\lambda' \sqrt{f_k}$

$$A_k - \mu_k I = Q_k R_k$$

$$A_{k+1} = R_k G_k + \mu_k I$$

$A_{k+1} - \mu_k I = Q_k$

$A_k \rightarrow$



$$\left( \begin{array}{c|c} B_k & w_k \\ \hline r_k & t_k \end{array} \right) \quad \|R_k\| \rightarrow 0 \quad \text{as } k \rightarrow \infty$$

$$\begin{array}{c}
 Q_k \\
 R_k \\
 \left( \begin{array}{c|c} B_k - u_k & w_k \\ \hline r_k & \lambda_k - u_k \end{array} \right) = \left( \begin{array}{c|c} P_k & u_k \\ \hline v_k & \alpha_k \end{array} \right) \left( \begin{array}{c|c} S_k & t_k \\ \hline 0 & g_k \end{array} \right) \quad (1)
 \end{array}$$

$$\left( \begin{array}{c|c} B_{k+1} - u_k & w_{k+1} \\ \hline r_{k+1} & \lambda_{k+1} - u_k \end{array} \right) = \left( \begin{array}{c|c} S_k & t_k \\ \hline 0 & g_k \end{array} \right) \left( \begin{array}{c|c} P_k & u_k \\ \hline v_k & b_k \end{array} \right) \quad Q_k$$

$$v_k = v_k \cdot s_k \quad v_{k+1} = s_k v_k$$

↓

$$v_k = v_k \cdot s_k^{-1}$$

$$\|v_{k+1}\| \leq |s_k| \cdot \|v_k\| \cdot \|v_k\|$$

↓

$$\|v_k\| \leq \underbrace{\|s_k^{-1}\|}_{r_k} \cdot \|v_k\|$$

$$\left( \begin{array}{c|c} S_u & t_u \\ \hline 0 & S_u \end{array} \right) = \left( \begin{array}{c|c} P^* & V_k^* \\ \hline U_k^* & I_k \end{array} \right) \left( \begin{array}{c|c} R_u - e_u & C_k \\ \hline V_k & I_k \end{array} \right)$$

$$f_u = u_u^* w_k + \bar{\varphi}_u (\lambda_k - e_u)$$

$$|f_u| \leq |u_u \cdot w_k| + \bar{\varphi}_u (\underbrace{\lambda_u - e_u}_{\sigma_k})$$

$\{ \text{C. } \mu_u = \lambda_k \rightarrow \text{nn} \}$

$$|f_u| \leq \|u_u\| \cdot \|w_k\| = \|V_k\| \cdot \|U_k\| \leq$$

$$\underbrace{\sigma_k \cdot \|V_k\| \cdot \|U_k\|}$$

$$\|V_{k+1}\| \leq \underbrace{\sigma_k^2}_{\sigma_k} \|W_k\| \|V_k\|^2$$

$A_n$  für  $\lambda \geq 13\pi/2$

$$\|w_n\| \leq \|A_n\| = \|A\|$$

$$A_n = \left( \begin{array}{c|c} B_n & w_n \\ \hline v_n & * \end{array} \right)$$

$$w_n$$

$$A_{n+1} = \underline{\underline{Q_n^T A_n B_n}}$$

$$\|A_n\| \geq \underline{\underline{\|w_n\|}} \geq \|w_n\| + \epsilon$$

$$(A^* A = A A^*) \text{ ist } \text{diag}(A) \rightarrow C$$

$|z|$        $A_n$        $\rho$        $C$

$$\|w_n\| = \|v_n\|$$

$$A_k^* A_{k\lambda} = \left( \begin{array}{c|c} & v_{\lambda}^* \\ \omega_n^* & \hline x \end{array} \right) \left( \begin{array}{c|c} & \omega_k \\ v_k & \hline x \end{array} \right) =$$

$$\left( \begin{array}{c|c} & 1 \\ & 1 \\ \hline \|\nu_k\|^2 + x \end{array} \right)$$

$$A_n^* A_n = \left( \begin{array}{c|c} & \omega_n \\ v_n & \hline x \end{array} \right) \left( \begin{array}{c|c} & v_n^* \\ \omega_n^* & \hline x \end{array} \right) =$$

$$\left( \begin{array}{c|c} & 1 \\ & 1 \\ \hline \|\nu_n\|^2 + x^2 \end{array} \right) \Rightarrow \|\omega_n\| = \|\nu_n\|$$

$$\|v_{k+1}\| \leq \begin{cases} r_n^2 \|v_k\|^2 \|A\| & \text{if } A \text{ is} \\ \underline{r_k}^2 \|v_k\|^3 & \text{otherwise} \end{cases}$$

?  $r_k$   $\approx c$

$$r = \|S_k^{-1}\|$$

->  $\gamma_0 \cup (1) \rightsquigarrow$

$$P_k \cdot S_k = B_k - e_k$$

$$\underline{S_k^{-1}} = \underbrace{(B_k - e_k)^{-1}}_{\sim} \cdot \underline{\underbrace{P_k}_{\sim}}$$

$$r_k = \|S_k^{-1}\| \leq \|\underbrace{(B_k - e_k)^{-1}}_{\sim}\| = \overbrace{\text{sep}(e_k, B_k)}^{\sim}$$

$A_k$

$$\left( \begin{array}{c|c} B_k & w_k \\ \hline r_k & t_k \end{array} \right)$$

$\downarrow$

$$\left( \begin{array}{c|c} B & w_k \\ \hline 0 & \lambda \end{array} \right)$$

$$P_n = (B_n - \mu_n) S_n^{-1}$$

$\phi$

$$\mu_n \rightarrow \lambda$$

$\lambda \nearrow \sigma$

$A_n \in C_{\sigma}$

$$A_1 \in \mathbb{C}^{n \times n}$$

$$\|A_1\| \leq \|A\|$$

$$\lambda_k \rightarrow \lambda$$

$$\sigma(B_\alpha) \subseteq \sigma(A_\alpha)$$

$\lambda$

$$\tilde{\lambda}_k \rightarrow \lambda$$

$$m_k$$

$$\delta_{n,q} = \underbrace{\theta_n^*}_{\rightarrow} \delta_n \theta_n$$

$$W_n(1 - \mu I) = W_n$$

$$\underbrace{|\lambda_1 - \mu|}_{<} < |\lambda_2 - \mu|$$

$$A = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

$$\left( \begin{array}{c|c} x & x \\ \hline x & x \end{array} \right)$$

$\leftarrow \tau^{\rightarrow} \circ \tau^{\rightarrow 3} \circ \tau^{\rightarrow} \neq 1$

$A = L P U$        $\Rightarrow$   $L$  and  $U$  are closed  
 $\Rightarrow P$  is a  $\sigma$ -algebra -  $U$   
 $\underline{\text{and } P}$

$\cup E_i \subseteq E_i \Rightarrow P$  is a  $\sigma$ -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  $\sigma$ -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

$$\underbrace{P_1 E_i \wedge F_j}_{\cdot}$$

$$P_2 E_i \wedge F_j \quad \text{für } 3 \leq i \leq n$$

$$P_1 E_i = \{ e_{\pi, (1)}, \dots, e_{\pi, (i)} \}$$

$$\dim(P_1 E_i \wedge F_j) = \# \pi(\{1, \dots, i\}) \cap \{n-b+1, \dots, n\}$$

$i, j \in \mathbb{N}$   $\pi_1, \pi_2 \in S_n$   $\text{per } \underline{\text{def}}$

$$|\pi_1(\{1, \dots, i\} \cap \{j, \dots, n\})| =$$

$$(\pi_2(\{1, \dots, i\} \cap \{j, \dots, n\})) = a_{ij}$$

$$\pi_1 = \pi_2 \quad \text{sc}$$

$\Rightarrow$   $\sim$   $\text{Cnf}$   $\wedge$   $\forall$   $(\forall x \exists y \forall z \forall w)$

$\forall y \forall x \forall z \forall w \forall v$   $\vdash$   $A$

$$a_{ij} \in \dim(A E_i \cap F_j)$$

$: 2 \times 2 \quad A \quad \underline{\text{is def}}$

$$\underline{A E_1 = F_1} \quad \Rightarrow A = \begin{pmatrix} 0 & x \\ * & x \end{pmatrix}$$

$\pi(1) = 2$   $\vdash$   $\forall x \forall y \forall z \forall w$   $\sim p/c$

$$\pi(2) = 1$$

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

: QR  $\rightarrow \lambda^T, \{f_k\}$

$$A_K = \underbrace{Q_K R_K}_{L} + \mu_K I$$

$$A_{K+1} = \underbrace{R_K Q_K}_{L} + \mu_K I$$

$$\begin{matrix} \text{r/c} & \sum_j \cdot j & \rightarrow 1 & \rightarrow \text{size} & n^3 \\ \text{r/c} & \sum_j j & \rightarrow 1 & \rightarrow \text{size} & n^3 \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j & \rightarrow 0 & \rightarrow 1, 0, 1 & \sum \\ & & & & \downarrow \\ & & & : n^3 - \sum & \rightarrow 0' \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j & \rightarrow 13 & \text{diff. 1} \\ \rightarrow \text{size} & \rightarrow 1 & \rightarrow \text{size} & \rightarrow \text{size} \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j & \rightarrow 13 & \text{diff. 2} \\ \rightarrow \text{size} & \rightarrow 1 & \rightarrow \text{size} & \rightarrow \text{size} \end{matrix}$$

$$\begin{matrix} \text{r/c} & \sum_j j & \rightarrow 13 & \text{diff. H} \\ \rightarrow \text{size} & \rightarrow 1 & \rightarrow \text{size} & \rightarrow \text{size} \\ \text{size} & \rightarrow 1 & \rightarrow \text{size} & \rightarrow \text{size} \end{matrix}$$

$$H = \underbrace{\begin{pmatrix} * & * & * \\ * & * & * \\ 0 & * & * \end{pmatrix}}_{\text{Hess. eckig}}$$

$\lambda^1, \lambda^2$

$\gamma_1, \gamma_2$

$$HE_i \subseteq E_{i+1}$$

( $\forall i \in \mathbb{N} : E_i$ ) ist Ld

Wesentlich  $\cup$   $\gamma_1, \gamma_2$

$\cup H, H \subseteq \underline{H}$  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

$A = \bigcup_{k=1}^m H_k$ ,  $H_i \in \underline{\mathcal{H}}$

$$A = \left( \begin{array}{c|c} a & x \\ \hline y & A_1 \end{array} \right) \rightsquigarrow y \mapsto \begin{pmatrix} b \\ 0 \\ \vdots \\ 0 \end{pmatrix}$$

$$\left( \begin{array}{c|c} a' & \rightsquigarrow \\ \hline b & A_1 \\ \hline 0 & \end{array} \right)$$

$$b = \|y\|$$

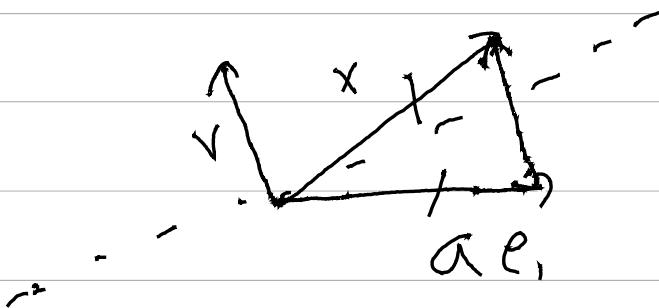
Q R Pls'z see if you're 8/6

1/3 ~J x 71671 μν',ιω

$$Qx = d \ell, \quad |d| = \|x\|, \quad , \quad \text{if } n^2 \text{ odd}$$

$\text{C}_2\text{C} \rightarrow \text{CS} \quad \text{Q} \quad \text{f}(13n) = \text{f}'(r)$

\* 819°C



about - 75% or so of the time

$$V = X - \alpha e_1, \quad -\delta \nearrow \text{JACU}$$

$\sqrt{12/100}/( \rightarrow \sqrt{3} )$  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

$$|\alpha| (= \|\mathbf{x}\|)$$

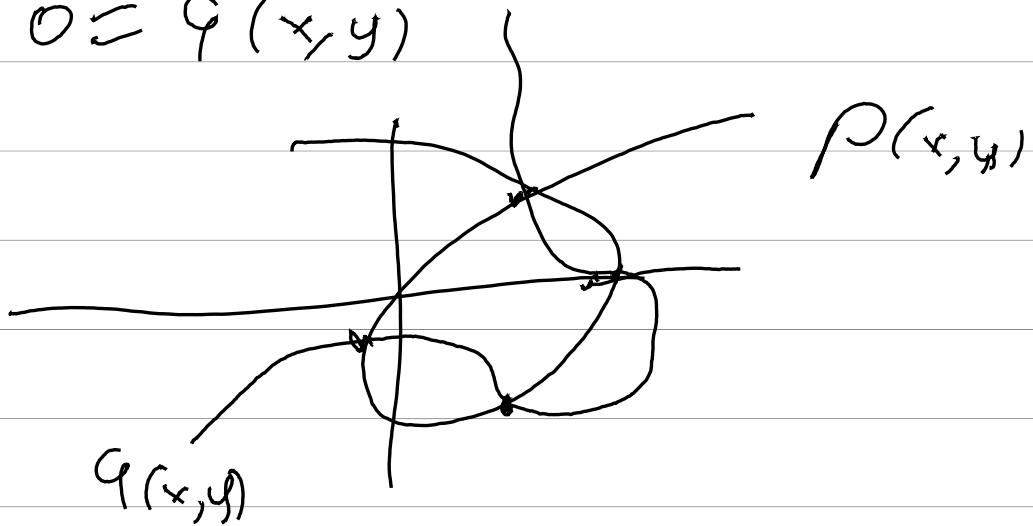
Numerical methods for solving linear systems

$$P_1(x) = 0, \dots, P_n(x) = 0$$

Wenn  $\mathbb{C}$  für  $x$  ist  $P_i$ :

$$\begin{aligned} xy = 0 &\Rightarrow \begin{cases} x = 0 \\ y = 0 \end{cases} \\ x = 0 \end{aligned}$$

$$P(x, y) = 0 = Q(x, y)$$



$$P_1, \dots, P_\alpha$$

$$P_1(\bar{a}) = \dots = P_\alpha(\bar{a})$$

$$q_1, \dots, q_n \quad \text{numbers} \quad p' \quad \text{etc}$$

$\rightsquigarrow$

$$\underbrace{q_1 P_1 + \dots + q_n P_n}_{= 1}$$

$\Rightarrow \zeta : \text{Complex plane} \rightarrow \text{Unit circle}$

numbers like  $\zeta^k$  ( $k \in \mathbb{Z}$ )

$(\zeta^n, \zeta^{n+1}, \dots, \zeta^{n+k})$

length of  $\zeta$  is  $n$ .  $\zeta^k$  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<sub>r</sub> P - фк  $\cong$   $\underbrace{\mathbb{C}^*}_{r=0}$

0 > 0 & d' > S<sub>r</sub>  $\Rightarrow$   $\mathbb{R}^*$

$$P_t(x) = X^n + (1-t) \sum_{i < n} a_i x^i$$

$$P_0 = P \quad P_1 = X^n$$

$P_t(a) \neq 0$  для  $a \in S_r$ ,  $t \in \mathbb{R}$

$f \approx g$   $\Leftrightarrow P_t : S_r \rightarrow \mathbb{C} \setminus \{0\}$

$e^t \circ f, g : S_r \rightarrow \mathbb{C} \setminus \{0\}$

$$H(a, t) = f(a) e^{tg(a)}, \quad H(a, 0) = f(a), \quad H(a, 1) = g(a)$$

$$P \sim P_0$$

$\sim \mathcal{N}'_{IC, \gamma}$

$$P_0(x) = \sum_{n \in \mathbb{N}} f_n P_{\text{def}} \geq P_{\text{def}} \cdot n^{\alpha}$$

$$H(a, t) = P((1-t) \cdot a) \quad \xrightarrow{\quad} \underline{P \circ a}$$

$$\gamma' \partial / \partial \gamma \quad \cancel{z \mapsto z^n - 1} \quad \cup \cup \beta \sim$$

$$\rightarrow \gamma \circ \gamma' \circ \delta$$

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

$$\text{, initial value problem} \quad q_1(\tilde{x}) = \dots = q_n(\tilde{x}) = 0$$

$$\underline{h}(\tilde{x}, t)$$

$$h(\tilde{x}, 1) = P(\tilde{x}) \quad h(\tilde{x}, 0) = \underline{q}(\tilde{x}) \quad \rightarrow \text{LCS}$$

$$\text{Initial value problem, } q(\tilde{x}_0) = 0 \quad \text{at } t=0$$

$$\tilde{x}(0) = \tilde{x}_0, \quad h(\tilde{x}(t), t) = 0 \quad \rightarrow \quad \underline{\tilde{x}(t)}$$

$$\text{at } t=0 \quad \rightarrow \quad \tilde{x}(1) \quad \text{at } t=1$$

$$P, q: \mathbb{R}^n \rightarrow \mathbb{R}^n \quad . \quad P(\tilde{x}) \neq 0$$

$$P_1(x, y) = \underbrace{x^2 + 4y^2 - 4}_{{}'/(r^2/3)} = 0$$

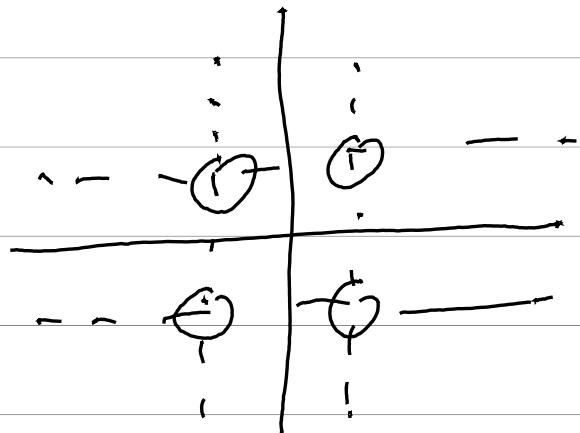
$$P_2(x, y) = 2y^2 - x = 0$$

$$q_1(x, y) = \underbrace{x^2 - 1}, \quad q_2(x, y) = \underbrace{y^2 - 1}$$

$$h(x, y, t) = (1-t) \cdot \tilde{q}(x, y) + t \cdot \tilde{p}(x, y)$$

$$\underbrace{x^2 - 1}_{{}''} = 0$$

$$(x-1) \cdot (x+1)$$



$$P_1(x, y) = \underline{y} = 0$$

curve

$$P_2(x, y) = \underline{y - r(x)}$$

surface  $r(x)$

$$r(x) = x^2 + 1$$

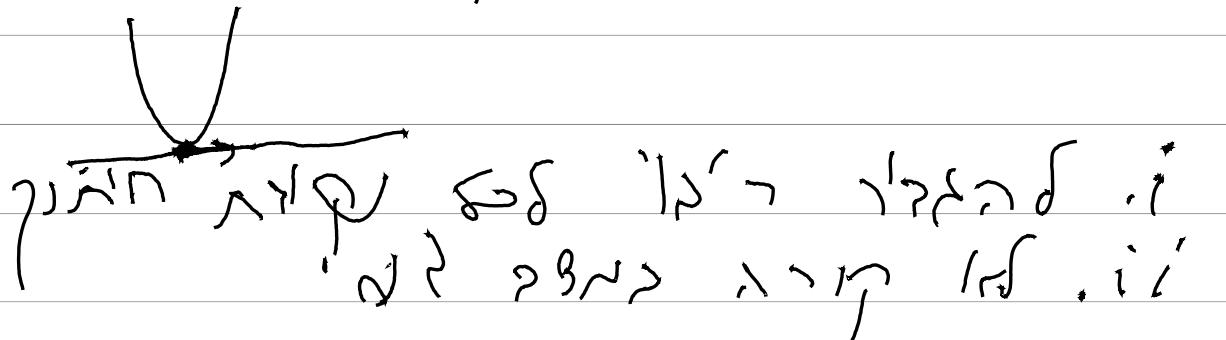
$f(x)$

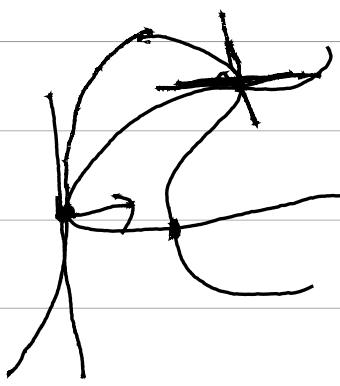
$$\mathbb{R} \rightarrow \mathbb{R} \rightarrow \text{Mild } f(x)$$

(-f)  $\rightarrow$  mild surface  $r(x)$

smooth curve  $x^2 + 1$

$$\text{smooth } r(x) = x^2$$





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 מילס' 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' מילס'

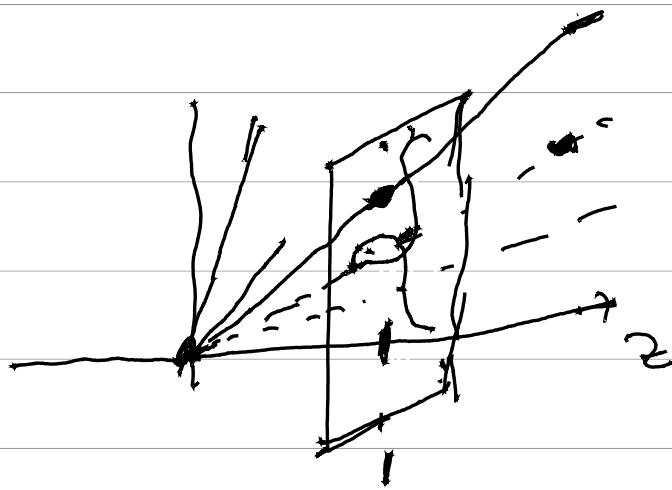
ט'ג'לולן ס'ס'

$$f(x) = 1 \quad \text{ל'}$$

$$y=0, \quad y=1$$

ט'ג'לולן ס'ס'

('אינטגרל נורמליזציה של פונקציית הסתברות כפונקציית גודל נורמליזציה)



$\forall x \forall y \forall z (x = y \wedge x = z \rightarrow y = z)$

$$\mathbb{K}^3 - \{(x, y, z) \mid z = 1\}$$

18 Pfu λ3'g 50 w'sn ..

• ०, प ग्रन्ती राज्य ग्रंथि ग्रंथि

$$\mathbb{P}^n = \left\{ I \subseteq \mathbb{K}^{n+1} \mid \begin{array}{l} \text{rank } I = n \\ \text{dim } \mathbb{K}^I = 1 \end{array} \right\}$$

• IP  $\hookrightarrow$   $\text{ס'ונתְּסִינְטָה}$   $\text{אַנְטֵרְגְּוֹן}$   $\text{אַנְטֵרְגְּוֹן}$   $\text{אַנְטֵרְגְּוֹן}$   $\text{אַנְטֵרְגְּוֹן}$   $\text{אַנְטֵרְגְּוֹן}$

$P(x, y, z)$

$$\frac{x^2 + y^2 = 1}{}$$

$$x = \frac{x'}{z}, \quad y = \frac{y'}{z} \Rightarrow$$

$$\frac{x'^2}{z^2} + \frac{y'^2}{z^2} = 1$$

$$P(x, y, z) =$$

$$\cancel{x^2 + y^2 = z^2}$$

$$\left| \begin{array}{l} P(x_0, \dots, x_n) \text{ ist} \\ \text{ ein } n\text{-dimensionaler } \int \text{ auf } \\ P = 0 \quad \text{sic} \\ \Rightarrow \exists x_0, \dots, x_n \in \\ \mathbb{R}^n \quad \rightarrow \\ \end{array} \right.$$

$$(1, 1, 1)$$

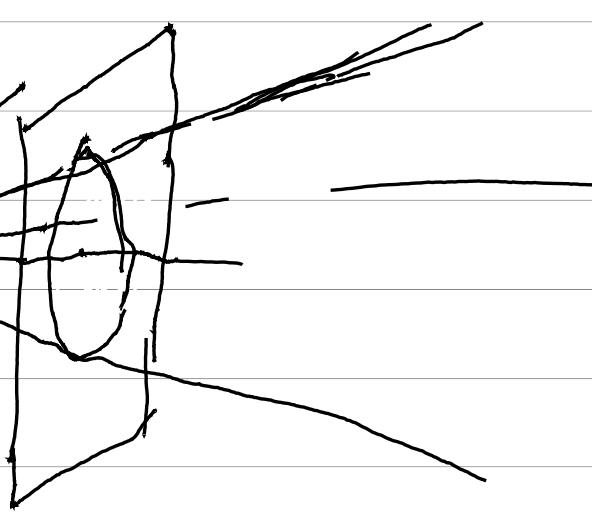
$$\frac{x'^2 + y'^2 = 0}{}$$

$$(\Leftrightarrow z = 0)$$

$$P(1, 1, 1) = 1$$

$$P(2, 2, 2) = 1$$

$$P(\lambda \cdot v) = \lambda^n P(v)$$



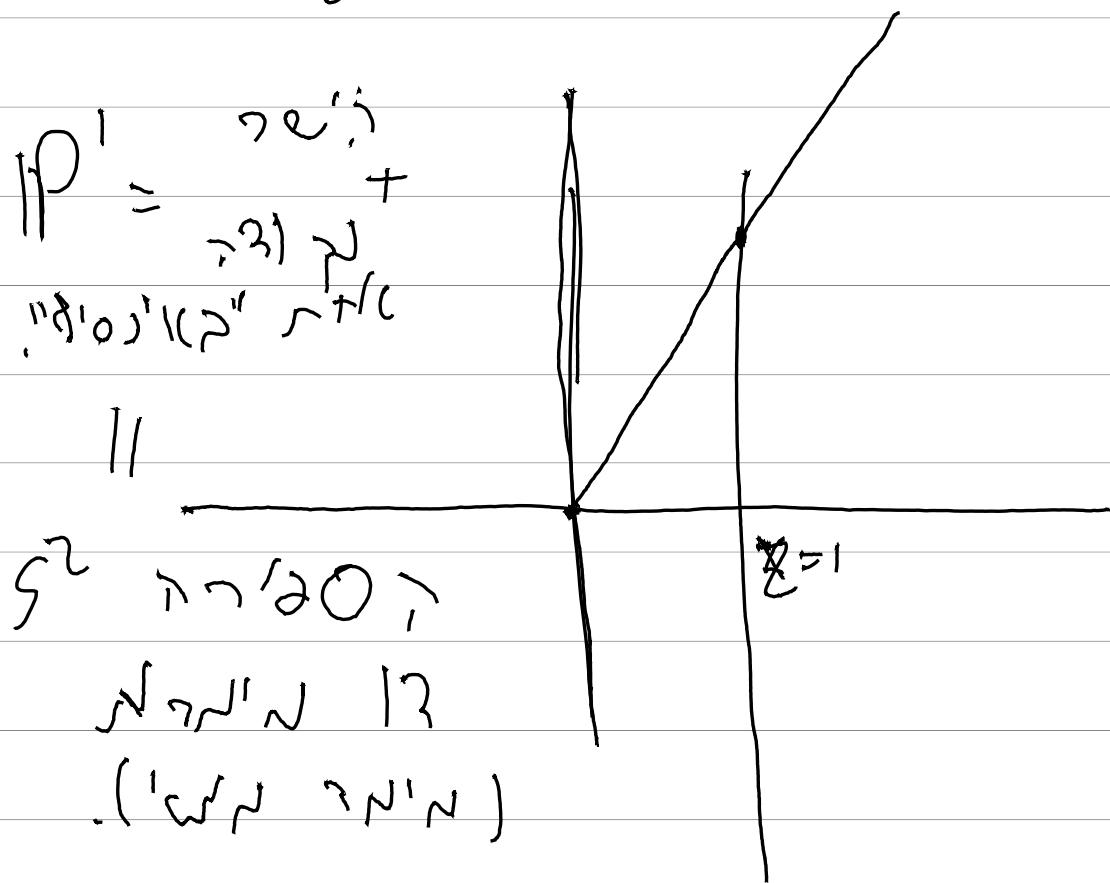
$$y = 0 \quad y = 1$$

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

$$y' = 0 \quad y' = 2 \quad \Rightarrow$$

$$z = 0$$

$$|P|^1 = \text{sum} + \text{sum} + \text{sum}$$



ר' נייר ווּ כָּלְבָן : ISP Com

P<sub>n</sub>(x<sub>0</sub>, ..., x<sub>n</sub>), P<sub>1</sub>(x<sub>0</sub>, ..., x<sub>n</sub>) מילויים

x<sub>0</sub>, ..., x<sub>i</sub> מושג מילויים

מילוי מושג מילויים P<sub>i</sub>-

הו גלויה מילויים מילויים

מונוטון (מילויים מילויים)

d<sub>1</sub>, ..., d<sub>n</sub> מילויים מילויים מילויים

המילויים מילויים מילויים מילויים

P<sub>i</sub>

$\sqrt{f_0} \approx n$   $P_2, P_1 - 1$   $n=2$   $\omega/c$

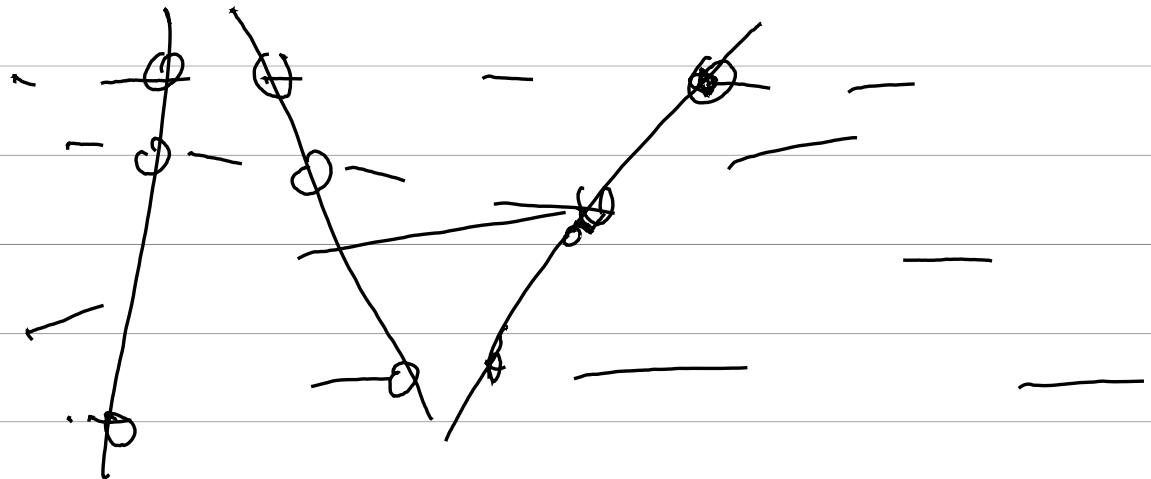
$\sim \gamma J \delta \omega / \hbar \omega_0$   $d_2 - 1$   $\underline{d}_1$   $\hbar$

$\mu U_{1,2,3} \sim \gamma^2 / \hbar \gamma \propto -\omega \gamma J J$

$\gamma^2 / \hbar \gamma \propto -1$   $f = 0$   $\nabla$

$\gamma^2 / \hbar \gamma \propto f, g = 0$   $\propto \omega J_1 m_2 \propto$

$X \otimes Y \propto f \cdot g = 0$   $\propto \omega J_1 m_2 \propto -1$   
 $P_1$



$$\underline{x^2 + 4y^2 - 4 = 0}$$

$$= \bar{P}(x, y)$$

$$\underline{2y^2 - x = 0}$$

$$\therefore$$

$$x^2 - 1 = 0$$

$$= \hat{q}(x, y)$$

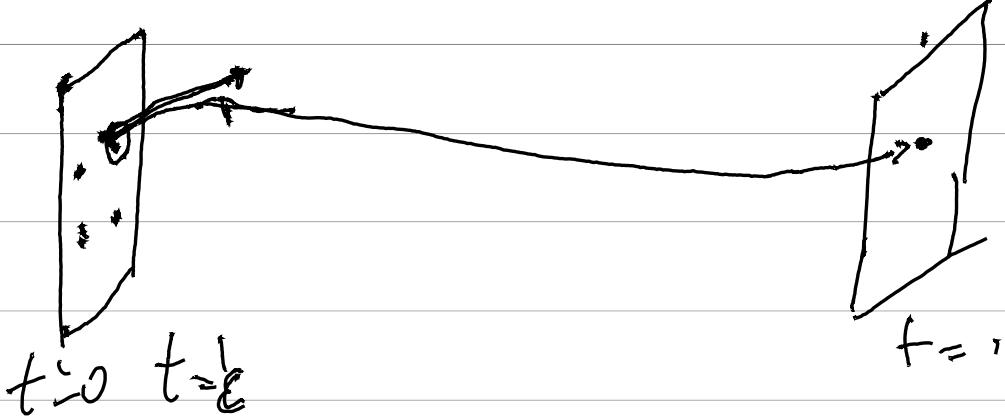
$$y^2 - 1 = 0$$

$$h(x, y, t) = (1-t)\bar{q} + t \cdot \bar{P}$$

$$y_0 - x_0 = 1$$

$$h(x_0, y_0, 0) = 0$$

$\text{arc: } \gamma_{\text{Natur}}$   $\gamma_{\text{Bsp/Ex}}$   $\text{Gesw}$



$h(x, y, t) \approx$

$t$  לש  $\dot{x}, \dot{y}$  כ  $x, y$  ו  $\sqrt{t} \rightarrow \gamma^2 \ln$

ט  $(x_0, y_0)$  לש  $\gamma^2 \ln$

$$\left( \begin{array}{c} \frac{\partial h_1}{\partial x} \cdot \frac{\partial h_1}{\partial y} \\ \frac{\partial h_2}{\partial x} \cdot \frac{\partial h_2}{\partial y} \end{array} \right)$$

↙

$\{0, 1\} \ni t - \int \ln \gamma^2 \ln \gamma$

ל  $\gamma^2 \ln \gamma$  כ  $\ln \gamma$  יתג

ל  $\gamma^2 \ln \gamma$  כ  $\ln \gamma$  כ  $\gamma^2$  כ  $\gamma^2$

$$(1-t)(x^2 - 1) +$$

$$t(x^2 + uy^2 - 4) = 0$$

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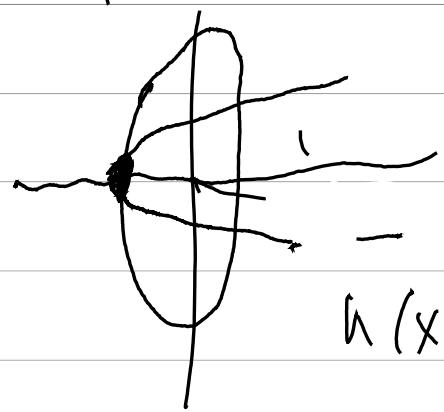
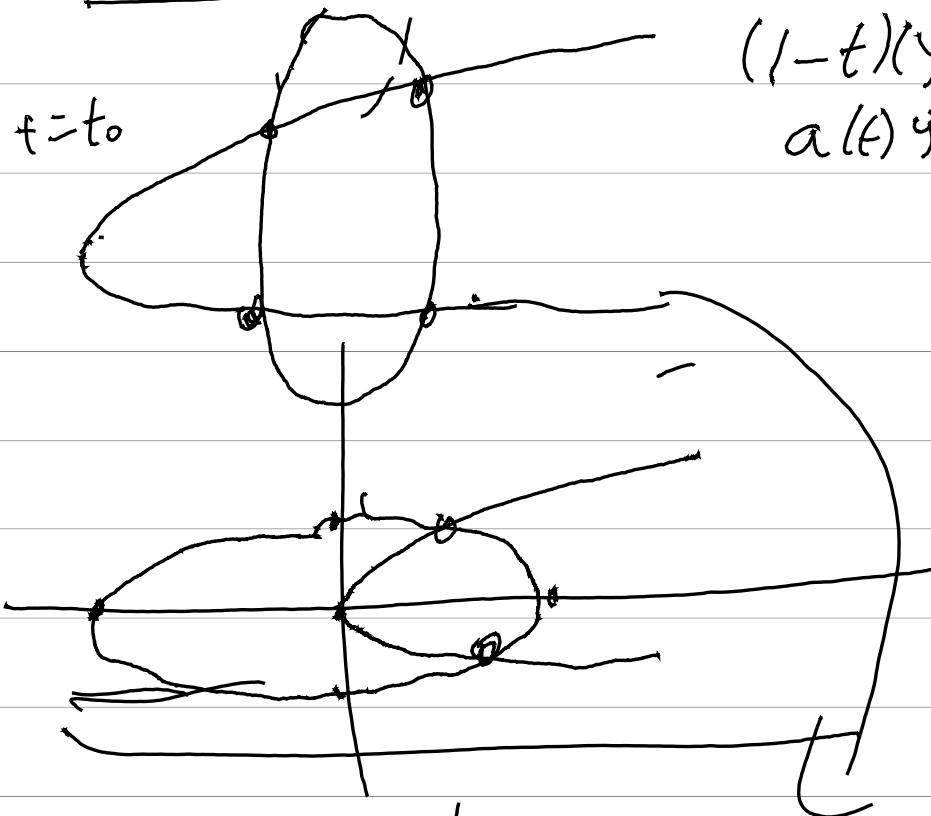
$$\underline{x^2 + uy^2 + t - 1 - ht = 0}$$

$$(1-t)(y^2 - 1) + t(2y^2 - x) =$$

$$a(t)y^2 + b(t) \cdot x = c(t)$$

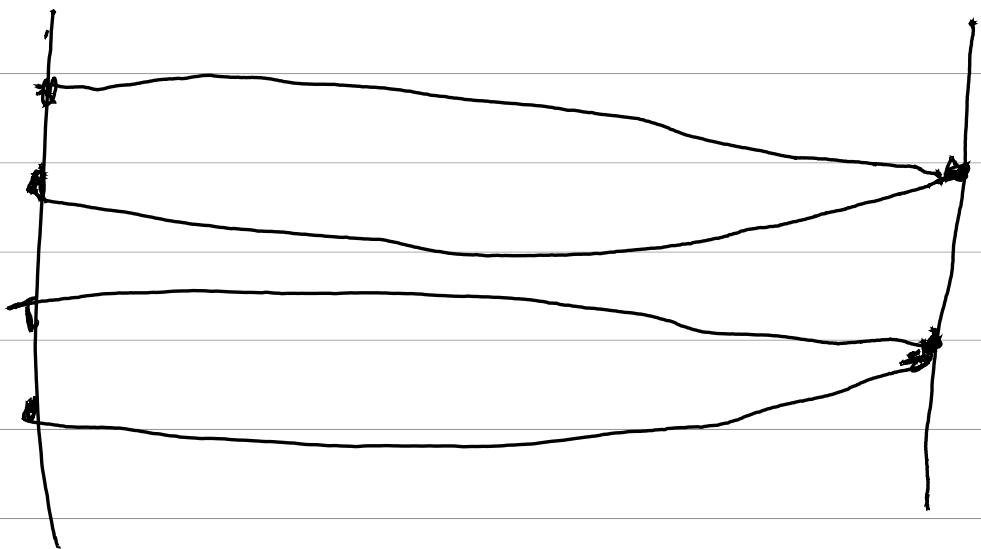
$$\underline{x^2 + uy^2 - 4 = 0}$$

$$2y^2 - x = 0$$



снабж , выясни  
и сюда

$$u(x, y, t) = \underline{\lambda(1-t)\vec{g} + t \cdot \vec{p}}$$



$$t \in \{0,1\}$$