Standard vs. Nested Form

$$\text{Standard Form: } a_0 + a_1 x + a_2 x^2 + \cdots + a_n x^n$$
$$\text{Nested Form: } a_0 + x(a_1 + a_2 x + \cdots + a_n x^{n-1})$$

Sig Fig Rounding

4-Digit Example

37.21429	37.21
0.002271828	0.002272
3000527.11059	3001000

Bit Preciscion

	sign	exponent	mantissa	machine ϵ
single	1	8	23	2^{-23}
double (default)	1	11	52	2^{-52}
long double	1	15	64	2^{-64}

sign	mantissa	exponent

$\rightarrow 1.b_1 b_2 \cdots b_n \times 2^P$

Error Calculation

$$x_e = \text{Exact},\ x_a = \text{Approximate}$$
$$\text{Abs err} = |x_e - x_a|$$
$$\text{Rel err} = \frac{|x_e - x_a|}{x_e}$$
$$\text{Worst case error} = 0.5 \cdot 10^{-P+1}$$

Loss of Significance

$$a - b = \frac{a^2 - b^2}{a + b}$$

Theorems

Intermediate Value Theorem

If $f(x)$ is continuous on $[a, b]$ and $f(a) \neq f(b)$,
then for any y in $[f(a),\ f(b)]$ $\exists\, c \in [a, b]$ such that $f(c) = y$

Mean Value Theorem

If $f'(x)$ is continuous on $[a, b]$,
then $\exists\, c \in [a, b]$ such that $f'(c) = (f(b) - f(a))/(b - a)$

Rolle's Theorem

If $f'(x)$ is continuous on $[a, b]$ and $f(a) = f(b)$,
then $\exists\, c \in [a, b]$ such that $f'(c) = 0$

Taylor Series

$$P_k(x) = \sum_{n=0}^{k} \frac{f^{(n)}(a)}{n!}(x - a)^n$$
$$E_{k+1} = \frac{f^{(k+1)}(c)}{(k+1)!}(x - x_0)^{k+1}$$

Matrix

Gaussian Elimination $O(\frac{2n^3}{3})$

Back Substitution $O(n^2)$

LU Factorization Gaussian + 2 * Back Sub

Methods

Bisection Method

1. Choose a, b such that $f(a) \cdot f(b) < 0$
2. Compute $c = \frac{a+b}{2}$
3. If $f(c)$ and $f(a)$ have opposite signs, then $b = c$
4. If $f(c)$ and $f(b)$ have opposite signs, then $a = c$
5. If $|b - a| < \epsilon$ or $f(c) = 0$ then c is the solution

$$\text{Error} = \frac{b - a}{2^{n+1}}$$
$$\text{Steps}(\epsilon) = \left\lceil \frac{\ln(b-a) - \ln(\epsilon)}{\ln(2)} - 1 \right\rceil$$

Newton's Method

1. $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$
2. If $|x_1 - x_0| < \epsilon$ or $f(x_1) = 0$ then x_1 is the solution

Multiplicity

$$\text{If } f^{(m-1)}(r_0) = 0 \text{ and } f^{(m)}(r_0) \neq 0,$$
$$\text{then } f^{(m)}(r_0) \text{ is a root of multiplicity } m$$

Convergence

$m = 1$	$m > 1$
$M = \frac{1}{2}\left\lvert\frac{f''(r_0)}{f'(r_0)}\right\rvert$	$e_{i+1} \approx \frac{m-1}{m} e_i$
$e_{i+1} \approx M e_i^2$	

Secant Method

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

Convergence

$$e_{i+1} \approx M e_i^p$$
$$p = \frac{1 + \sqrt{5}}{2} \text{ (Golden Ratio)}$$

False Position Method

Same as Bisection Method, but

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

Convergence - Generally same as Bisection

Fixed Point Iteration

1. Solve $f(x)$ for $x = g(x)$

$$\begin{aligned} g(x) = 2.8x - x^2 &= x \\ 1.8x - x^2 &= 0 \\ x(1.8 - x) &= 0 \\ x &= 0, 1.8 \end{aligned}$$

$$f(x) = 2x^3 - 6x - 1$$
$$g(x) = \frac{2x^3 - 1}{6}$$

2. If $|g'(r_n)| < 1$, fixed point will converge to r_n

LU Factorization on back