Diferencias divididas

Polinomio de newton

$$P_n(x) = \sum_{i=0}^{n} f[x_0,\ldots,x_i]Q_i(x).$$

$$\begin{aligned} P_n(x) &= f[x_0] + f[x_0,x_1]Q_1(x) + f[x_0,\ldots,x_2]Q_2(x) + \\ &\quad + f[x_0,\ldots,x_3]Q_3(x) + \cdots + f[x_0,\ldots,x_n]Q_n(x). \end{aligned}$$

Propiedad recursiva

$$f[x_0,\ldots,x_k] = \frac{f[x_1,\ldots,x_k] - f[x_0,\ldots,x_{k-1}]}{x_0 - x_k}$$

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Propiedad recursiva

$$f[x_0, \ldots, x_k] = \frac{f[x_1, \ldots, x_k] - f[x_0, \ldots, x_{k-1}]}{x_0 - x_k}$$

Diferencias divididas

Polinomio de newton

$$P_n(x) = \sum_{i=0}^{n} f[x_0, \ldots, x_i] Q_i(x).$$

$$\begin{aligned} P_n(x) \quad &= \quad f[x_0] + f[x_0, x_1] Q_1(x) + f[x_0, \ldots, x_2] Q_2(x) + \\ &\quad + f[x_0, \ldots, x_3] Q_3(x) + \cdots + f[x_0, \ldots, x_n] Q_n(x). \end{aligned}$$

Propiedad recursiva

$$f[x_0, \ldots, x_k] = \frac{f[x_1, \ldots, x_k] - f[x_0, \ldots, x_{k-1}]}{x_0 - x_k}$$

x_0	$f[x_0]$
x_1	$f[x_1]$
x_2	$f[x_2]$
x_3	$f[x_3]$
x_4	$f[x_4]$
x_5	$f[x_5]$
	orden 0

$$
\begin{array}{llll}
x_0 & f[x_0] & & \\
 & & f[x_0,x_1] = \frac{f[x_0]-f[x_1]}{x_0-x_1} & \\
x_1 & f[x_1] & & \\
 & & f[x_1,x_2] = \frac{f[x_1]-f[x_2]}{x_1-x_2} & \\
x_2 & f[x_2] & & \\
 & & f[x_2,x_3] = \frac{f[x_2]-f[x_3]}{x_2-x_3} & \\
x_3 & f[x_3] & & \\
 & & f[x_3,x_4] = \frac{f[x_4]-f[x_3]}{x_4-x_3} & \\
x_4 & f[x_4] & & \\
 & & f[x_4,x_5] = \frac{f[x_4]-f[x_5]}{x_4-x_5} & \\
x_5 & f[x_5] & &
\end{array}
$$

orden 0 orden 1

x_0	$f[x_0]$		
		$f[x_0,x_1]$	
x_1	$f[x_1]$		$f[x_0,x_1,x_2] = \frac{f[x_1,x_2]-f[x_0,x_1]}{x_2-x_0}$
		$f[x_1,x_2]$	
x_2	$f[x_2]$		$f[x_1,x_2,x_3] = \frac{f[x_2,x_3]-f[x_1,x_2]}{x_3-x_1}$
		$f[x_2,x_3]$	
x_3	$f[x_3]$		$f[x_2,x_3,x_4] = \frac{f[x_3,x_4]-f[x_2,x_3]}{x_4-x_2}$
		$f[x_3,x_4]$	
x_4	$f[x_4]$		$f[x_3,x_4,x_5] = \frac{f[x_4,x_5]-f[x_3,x_4]}{x_5-x_3}$
		$f[x_4,x_5]$	
x_5	$f[x_5]$		
	orden 0	orden 1	orden 2

x_0	$f[x_0]$			
		$f[x_0,x_1]$		
x_1	$f[x_1]$		$f[x_0,x_1,x_2]$	
		$f[x_1,x_2]$		$f[x_0,x_1,x_2,x_3] = \cdots$
x_2	$f[x_2]$		$f[x_1,x_2,x_3]$	
		$f[x_2,x_3]$		$f[x_1,x_2,x_3,x_4] = \cdots$
x_3	$f[x_3]$		$f[x_2,x_3,x_4]$	
		$f[x_3,x_4]$		$f[x_2,x_3,x_4,x_5] = \cdots$
x_4	$f[x_4]$		$f[x_3,x_4,x_5]$	
		$f[x_4,x_5]$		
x_5	$f[x_5]$			
	orden 0	orden 1	orden 2	orden 3

x(:)	A(:,1)			
x_0	$f[x_0]$			
		$f[x_0,x_1]$		
x_1	$f[x_1]$		$f[x_0,x_1,x_2]$	
		$f[x_1,x_2]$		$f[x_0,x_1,x_2,x_3] = \cdots$
x_2	$f[x_2]$		$f[x_1,x_2,x_3]$	
		$f[x_2,x_3]$		$f[x_1,x_2,x_3,x_4] = \cdots$
x_3	$f[x_3]$		$f[x_2,x_3,x_4]$	
		$f[x_3,x_4]$		$f[x_2,x_3,x_4,x_5] = \cdots$
x_4	$f[x_4]$		$f[x_3,x_4,x_5]$	
		$f[x_4,x_5]$		
x_5	$f[x_5]$			
	orden 0	orden 1	orden 2	orden 3

x(:)	A(:,1)	A(:,2)		
x_0	$f[x_0]$			
		$f[x_0,x_1]$		
x_1	$f[x_1]$		$f[x_0,x_1,x_2]$	
		$f[x_1,x_2]$		$f[x_0,x_1,x_2,x_3] = \cdots$
x_2	$f[x_2]$		$f[x_1,x_2,x_3]$	
		$f[x_2,x_3]$		$f[x_1,x_2,x_3,x_4] = \cdots$
x_3	$f[x_3]$		$f[x_2,x_3,x_4]$	
		$f[x_3,x_4]$		$f[x_2,x_3,x_4,x_5] = \cdots$
x_4	$f[x_4]$		$f[x_3,x_4,x_5]$	
		$f[x_4,x_5]$		
x_5	$f[x_5]$			
	orden 0	orden 1	orden 2	orden 3

x(:)	A(:,1)	A(:,2)	A(:,3)	
x_0	$f[x_0]$			
		$f[x_0,x_1]$		
x_1	$f[x_1]$		$f[x_0,x_1,x_2]$	
		$f[x_1,x_2]$		$f[x_0,x_1,x_2,x_3]=\cdots$
x_2	$f[x_2]$		$f[x_1,x_2,x_3]$	
		$f[x_2,x_3]$		$f[x_1,x_2,x_3,x_4]=\cdots$
x_3	$f[x_3]$		$f[x_2,x_3,x_4]$	
		$f[x_3,x_4]$		$f[x_2,x_3,x_4,x_5]=\cdots$
x_4	$f[x_4]$		$f[x_3,x_4,x_5]$	
		$f[x_4,x_5]$		
x_5	$f[x_5]$			
	orden 0	orden 1	orden 2	orden 3

x(:)	A(:,1)	A(:,2)	A(:,3)	A(:,4)
x_0	$f[x_0]$			
		$f[x_0,x_1]$		
x_1	$f[x_1]$		$f[x_0,x_1,x_2]$	
		$f[x_1,x_2]$		$f[x_0,x_1,x_2,x_3]=\cdots$
x_2	$f[x_2]$		$f[x_1,x_2,x_3]$	
		$f[x_2,x_3]$		$f[x_1,x_2,x_3,x_4]=\cdots$
x_3	$f[x_3]$		$f[x_2,x_3,x_4]$	
		$f[x_3,x_4]$		$f[x_2,x_3,x_4,x_5]=\cdots$
x_4	$f[x_4]$		$f[x_3,x_4,x_5]$	
		$f[x_4,x_5]$		
x_5	$f[x_5]$			
	orden 0	orden 1	orden 2	orden 3

x(:)	A(:,1)	A(:,2)	A(:,3)	A(:,4)
x(1)	A(1,1)			
		$f[x_0,x_1]$		
x(2)	A(2,1)		$f[x_0,x_1,x_2]$	
		$f[x_1,x_2]$		$f[x_0,x_1,x_2,x_3] = \cdots$
x(3)	A(3,1)		$f[x_1,x_2,x_3]$	
		$f[x_2,x_3]$		$f[x_1,x_2,x_3,x_4] = \cdots$
x(4)	A(4,1)		$f[x_2,x_3,x_4]$	
		$f[x_3,x_4]$		$f[x_2,x_3,x_4,x_5] = \cdots$
x(5)	A(5,1)		$f[x_3,x_4,x_5]$	
		$f[x_4,x_5]$		
x(6)	A(6,1)			
	orden 0	orden 1	orden 2	orden 3

x(:)	A(:,1)	A(:,2)	A(:,3)	A(:,4)
x(1)	A(1,1)			
		A(1,2)= $\frac{\text{A(1,1)-A(2,1)}}{\text{x(1)-x(2)}}$		
x(2)	A(2,1)		$f[x_0,x_1,x_2]$	
		A(2,2)= $\frac{\text{A(2,1)-A(3,1)}}{\text{x(2)-x(3)}}$		$f[x_0,x_1,x_2,x_3] = \cdots$
x(3)	A(3,1)		$f[x_1,x_2,x_3]$	
		A(3,2)= $\frac{\text{A(3,1)-A(4,1)}}{\text{x(3)-x(4)}}$		$f[x_1,x_2,x_3,x_4] = \cdots$
x(4)	A(4,1)		$f[x_2,x_3,x_4]$	
		A(4,2)= $\frac{\text{A(4,1)-A(5,1)}}{\text{x(4)-x(5)}}$		$f[x_2,x_3,x_4,x_5] = \cdots$
x(5)	A(5,1)		$f[x_3,x_4,x_5]$	
		A(5,2)= $\frac{\text{A(5,1)-A(6,1)}}{\text{x(5)-x(6)}}$		
x(6)	A(6,1)			
	orden 0	orden 1	orden 2	orden 3

x(:)	A(:,1)	A(:,2)	A(:,3)	A(:,4)
x(1)	A(1,1)			
		$A(1,2)=\frac{A(1,1)-A(2,1)}{x(1)-x(2)}$		
x(2)	A(2,1)		$A(1,3)=\frac{A(1,2)-A(2,2)}{x(1)-x(3)}$	
		$A(2,2)=\frac{A(2,1)-A(3,1)}{x(2)-x(3)}$		$f[x_0,x_1,x_2,x_3$
x(3)	A(3,1)		$A(2,3)=\frac{A(2,2)-A(3,2)}{x(2)-x(4)}$	
		$A(3,2)=\frac{A(3,1)-A(4,1)}{x(3)-x(4)}$		$f[x_1,x_2,x_3,x_4$
x(4)	A(4,1)		$A(3,3)=\frac{A(3,2)-A(4,2)}{x(3)-x(5)}$	
		$A(4,2)=\frac{A(4,1)-A(5,1)}{x(4)-x(5)}$		$f[x_2,x_3,x_4,x_5$
x(5)	A(5,1)		$A(4,3)=\frac{A(4,2)-A(5,2)}{x(4)-x(6)}$	
		$A(5,2)=\frac{A(5,1)-A(6,1)}{x(5)-x(6)}$		
x(6)	A(6,1)			
	orden 0	orden 1	orden 2	orden

x(:)	A(:,1)	A(:,2)	A(:,3)	A(:,4)
x(1)	A(1,1)			
		$A(1,2)=\frac{A(1,1)-A(2,1)}{x(1)-x(2)}$		
x(2)	A(2,1)		$A(1,3)=\frac{A(1,2)-A(2,2)}{x(1)-x(3)}$	
		$A(2,2)=\frac{A(2,1)-A(3,1)}{x(2)-x(3)}$		$A(1,4)=\cdots$
x(3)	A(3,1)		$A(2,3)=\frac{A(2,2)-A(3,2)}{x(2)-x(4)}$	
		$A(3,2)=\frac{A(3,1)-A(4,1)}{x(3)-x(4)}$		$A(2,4)=\cdots$
x(4)	A(4,1)		$A(3,3)=\frac{A(3,2)-A(4,2)}{x(3)-x(5)}$	
		$A(4,2)=\frac{A(4,1)-A(5,1)}{x(4)-x(5)}$		$A(3,4)=\cdots$
x(5)	A(5,1)		$A(4,3)=\frac{A(4,2)-A(5,2)}{x(4)-x(6)}$	
		$A(5,2)=\frac{A(5,1)-A(6,1)}{x(5)-x(6)}$		
x(6)	A(6,1)			
	orden 0	orden 1	orden 2	orden 3

$$A(k,j)=\frac{A(k,j-1)-A(k+1,j-1)}{x(k)-x(k+j-1)}$$

```
function w=diferencias(x,y)
n=columns(x);
A=zeros(n,n);
A(:,1)=y';
w=zeros(1,n);
w(1)=y(1);
for j=2:n
  for k=1:n-j+1
    A(k,j)=(A(k,j-1)-A(k+1,j-1))/(x(k)-x(k+j-1));
  end
  w(j)=A(1,j);
end
endfunction
```

$$A(k,j)=\frac{A(k,j-1)-A(k+1,j-1)}{x(k)-x(k+j-1)}$$

```
function w=diferencias(x,y)
n=columns(x);
A=zeros(n,n);
A(:,1)=y';
w=zeros(1,n);
w(1)=y(1);
for j=2:n
  for k=1:n-j+1
    A(k,j)=(A(k,j-1)-A(k+1,j-1))/(x(k)-x(k+j-1));
  end
  w(j)=A(1,j);
end
endfunction
```

```
function pz=evalnewton(c,x,z)
k=columns(c);
pz=zeros(size(z));
for j=1:k
 wj=c(j)*ones(size(z));
 for i=1:j-1
  wj=wj.*(z-x(i));
 end
 pz=pz+wj;
end
end
```

Multiplicación encajada - Método de Horner

$$p(x) = \sum_{i=0}^{n} a_i x^i.$$

$$\begin{aligned}
p(x) &= a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \cdots + a_n x^n \\
&= a_0 + x\left(a_1 + a_2 x + a_3 x^2 + \cdots + a_n x^{n-1}\right) \\
&= a_0 + x\left(a_1 + x\left(a_2 + a_3 x + \cdots + a_n x^{n-2}\right)\right) \\
&= a_0 + x\left(a_1 + x\left(a_2 + x\left(a_3 + \cdots + a_n x^{n-3}\right)\right)\right) \\
&\vdots \\
&= a_0 + x(a_1 + x(a_2 + x(a_3 + \cdots + x(a_{n-1} + x a_n))))
\end{aligned}$$

Multiplicación encajada - Método de Horner

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$$\begin{aligned}
p(x) &= a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \cdots + a_n x^n \\
&= a_0 + x\left(a_1 + a_2 x + a_3 x^2 + \cdots + a_n x^{n-1}\right) \\
&= a_0 + x\left(a_1 + x\left(a_2 + a_3 x + \cdots + a_n x^{n-2}\right)\right) \\
&= a_0 + x\left(a_1 + x\left(a_2 + x\left(a_3 + \cdots + a_n x^{n-3}\right)\right)\right) \\
&\vdots \\
&= a_0 + x(a_1 + x(a_2 + x(a_3 + \cdots + x(a_{n-1} + x a_n))))
\end{aligned}$$

$$p(x) = a_0 + x\,(a_1 + x\,(a_2 + x\,(a_3 + \cdots + x\,(a_{n-1} + xa_n))))$$

$$p(x) = \mathrm{a(1)} + x\,(\mathrm{a(2)} + x\,(\mathrm{a(3)} + x\,(\mathrm{a(4)} + \cdots + x\,(\mathrm{a(n)} + x\mathrm{a(n+1)}))))$$

$$p(x) = \mathrm{a(1)} + x$$

$$p(x) =$$

$$p(x) = a_0 + x\,(a_1 + x\,(a_2 + x\,(a_3 + \cdots + x\,(a_{n-1} + x a_n))))$$

$$p(x) = \mathrm{a(1)} + x\,(\mathrm{a(2)} + x\,(\mathrm{a(3)} + x\,(\mathrm{a(4)} + \cdots + x\,(\mathrm{a(n)} + x\mathrm{a(n+1)}))))$$

$$p(x) = \mathrm{a(1)} + x$$

$$p(x) =$$

$$p(x) = a_0 + x(a_1 + x(a_2 + x(a_3 + \cdots + x(a_{n-1} + xa_n))))$$

$$p(x) = \text{a(1)} + x(\text{a(2)} + x(\text{a(3)} + x(\text{a(4)} + \cdots + x(\text{a(n)} + x\text{a(n+1)})))))$$

$$p(x) = \text{a(1)} + x(\text{a(2)} + x(\text{a(3)} + x(\text{a(4)} + \cdots + x(\text{a(m-1)} + x))))$$

$$p(x) = \text{a(1)} + x(\text{a(2)} + x(\text{a(3)} + x(\text{a(4)} + \cdots + x(\text{a(m-1)} + x\text{a(m)}))))$$

$$p(x) = a_0 + x(a_1 + x(a_2 + x(a_3 + \cdots + x(a_{n-1} + xa_n))))$$

$$p(x) = \text{a(1)} + x(\text{a(2)} + x(\text{a(3)} + x(\text{a(4)} + \cdots + x(\text{a(n)} + x\text{a(n+1)})))))$$

$$p(x) = \text{a(1)} + x(\text{a(2)} + x(\text{a(3)} + x(\text{a(4)} + \cdots + x(\text{a(m-1)} + x\text{a(m)})))))$$

$$p(x) = \text{a(1)} + x(\text{a(2)} + x(\text{a(3)} + x(\text{a(4)} + \cdots + x(\text{a(m-1)} + x\text{w(m)})))))$$

$$p(x) = a_0 + x(a_1 + x(a_2 + x(a_3 + \cdots + x(a_{n-1} + xa_n))))$$

$$p(x) = \mathsf{a(1)} + x(\mathsf{a(2)} + x(\mathsf{a(3)} + x(\mathsf{a(4)} + \cdots + x(\mathsf{a(n)} + x\mathsf{a(n+1)})))))$$

$$p(x) = \mathsf{a(1)} + x(\mathsf{a(2)} + x(\mathsf{a(3)} + x(\mathsf{a(4)} + \cdots + x(\mathsf{a(m\text{-}1)} + x\mathsf{w(m)})))))$$

$$p(x) = \mathsf{a(1)} + x(\mathsf{a(2)} + x(\mathsf{a(3)} + x(\mathsf{a(4)} + \cdots + x\mathsf{w(m\text{-}1)}))))$$

$$p(x) = a_0 + x(a_1 + x(a_2 + x(a_3 + \cdots + x(a_{n-1} + xa_n))))$$

$$p(x) = \mathsf{a(1)} + x(\mathsf{a(2)} + x(\mathsf{a(3)} + x(\mathsf{a(4)} + \cdots + x(\mathsf{a(n)} + x\mathsf{a(n+1)})))))$$

$$p(x) = \mathsf{a(1)} + x(\mathsf{a(2)} + x(\mathsf{a(3)} + x(\mathsf{a(4)} + x\mathsf{w(5)}))))$$

$$p(x) = \mathsf{a(1)} + x(\mathsf{a(2)} + x(\mathsf{a(3)} + x\mathsf{w(4)})))$$

$$p(x) = a_0 + x\,(a_1 + x\,(a_2 + x\,(a_3 + \cdots + x\,(a_{n-1} + x a_n))))$$

$$p(x) = \mathsf{a(1)} + x\,(\mathsf{a(2)} + x\,(\mathsf{a(3)} + x\,(\mathsf{a(4)} + \cdots + x\,(\mathsf{a(n)} + x\mathsf{a(n+1)})))))$$

$$p(x) = \mathsf{a(1)} + x\,(\mathsf{a(2)} + x\,(\mathsf{a(3)} + x\mathsf{w(4)})\,)$$

$$p(x) = \mathsf{a(1)} + x\,(\mathsf{a(2)} + x\mathsf{w(3)})$$

$$p(x) = a_0 + x(a_1 + x(a_2 + x(a_3 + \cdots + x(a_{n-1} + xa_n))))$$

$$p(x) = \mathrm{a(1)} + x(\mathrm{a(2)} + x(\mathrm{a(3)} + x(\mathrm{a(4)} + \cdots + x(\mathrm{a(n)} + x\mathrm{a(n+1)})))))$$

$$p(x) = \mathrm{a(1)} + x(\mathrm{a(2)} + x\mathrm{w(3)}))$$

$$p(x) = \mathrm{a(1)} + x\mathrm{w(2)})$$

$$p(x) = a_0 + x\,(a_1 + x\,(a_2 + x\,(a_3 + \cdots + x\,(a_{n-1} + x a_n))))$$

$$p(x) = \mathsf{a(1)} + x\,(\mathsf{a(2)} + x\,(\mathsf{a(3)} + x\,(\mathsf{a(4)} + \cdots + x\,(\mathsf{a(n)} + x\mathsf{a(n+1)})))))$$

$$p(x) = \mathsf{a(1)} + x\mathsf{w(2)}$$

$$p(x) = \mathsf{w(1)}$$

$$p(x) = a_0 + x\left(a_1 + x\left(a_2 + x\left(a_3 + \cdots + x\left(a_{n-1} + xa_n\right)\right)\right)\right)$$

$$p(x) = \mathsf{a(1)} + x\left(\mathsf{a(2)} + x\left(\mathsf{a(3)} + x\left(\mathsf{a(4)} + \cdots + x\left(\mathsf{a(n)} + x\mathsf{a(n+1)}\right)\right)\right)\right)$$

$$p(x) = \mathsf{a(1)} + x\mathsf{w(2)}$$

$$p(x) = \mathsf{w(1)}$$

$$\mathsf{w(k)} = \mathsf{a(k)} + x\mathsf{w(k+1)}$$

```
function pz=horner(a,z)
m=columns(a);
pz=0*z;
for j=m:-1:1
  pz=a(j)+pz.*z;
end
endfunction
```

Multiplicación encajada para el método Newton

$$P_n(x) = \sum_{i=0}^{n} C_i Q_i(x).$$

$$Q_i(x) = Q_{i-1}(x)(x - x_i)$$

$$P_n(x) = c_0 + (x - x_1)\,(c_1 + (x - x_2)\,(c_2 + (x - x_3)\,(c_3 + \cdots)))$$

Multiplicación encajada para el método Newton

$$P_n(x) = \sum_{i=0}^{n} C_i Q_i(x).$$

$$Q_i(x) = Q_{i-1}(x)(x - x_i)$$

$$P_n(x) = c_0 + (x - x_1)\,(c_1 + (x - x_2)\,(c_2 + (x - x_3)\,(c_3 + \cdots)))$$

Multiplicación encajada para el método Newton

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newtonh.m

```
function pz=horner(c,x,z)
m=columns(c);
pz=0*z;
for j=m:-1:1
  pz=c(j)+pz.*(z-x(j));
end
endfunction
```

Errores y tiempos de ejecución en Newton

Interpolar la función $f(x) = x^k$ en el intervalo $[0{,}001, 1]$ usando los puntos $[0{,}001\ (1:k)/k]$. Calcular el valor de $P_k(1)$. Graficar los valores obtenidos para $k = 1:200$. Analizar los resultados obtenidos.

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