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DEPARTMENT OF INFORMATION AND COMMUNICATION TECHNOLOGY

Lab Report

Lab Report No : 04

Lab Report on : Study of different realization structures of digital filters using MATLAB.

Course Title : Digital Signal Processing Lab

Course Code : ICT-3206

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Introduction:

Digital filters are widely used in signal processing to modify or enhance signals. These filters can be implemented in different realization forms such as direct, parallel, and cascade structures. Each realization has its own advantages in terms of stability, complexity, and numerical accuracy. This experiment demonstrates parallel and cascade form realizations of FIR and IIR digital filters using MATLAB.

Objective:

- To realize an IIR filter in parallel form.
- To convert a direct form filter into cascade form.
- To implement FIR and IIR filters using cascade realization.

Theory:

- **Parallel form realization** represents a filter as a sum of first- or second-order subsystems using partial fraction expansion.
- **Cascade form realization** represents a filter as a product of second-order sections obtained from the roots of numerator and denominator polynomials.
- Cascade and parallel forms are preferred over direct form for better numerical stability.

MATLAB Code :

Program 1: Parallel Form Realization of IIR Filter

```
% Parallel form realization of IIR filters

clc; clear all; close all;
num = [2 10 23 34 31 16 4];
den = [36 78 87 59 26 7 1];

[r1 p1 k1] = residuez(num, den);
[r2 p2 k2] = residue(num, den);

disp('parallel form I')
disp('residues are')
disp(r1)
disp('poles are at')
disp(p1)
disp('constant value')
disp(k1)

disp('parallel form II')
disp('residues are')
disp(r2)
disp('poles are at')
disp(p2)
disp('constant value')
disp(k2)
```

Output:

```
parallel form I
residues are
  -0.5556 - 2.2785i
  -0.5556 + 2.2785i
  -0.5952 - 0.7561i
  -0.5952 + 0.7561i
  -0.8214 + 4.3920i
  -0.8214 - 4.3920i

poles are at
  -0.3333 + 0.4714i
  -0.3333 - 0.4714i
  -0.5000 + 0.2887i
  -0.5000 - 0.2887i
  -0.2500 + 0.4330i
  -0.2500 - 0.4330i

constant value
     4
```

```
parallel form II
residues are
   1.2593 + 0.4976i
   1.2593 - 0.4976i
   0.5159 + 0.2062i
   0.5159 - 0.2062i
  -1.6964 - 1.4537i
  -1.6964 + 1.4537i

poles are at
  -0.3333 + 0.4714i
  -0.3333 - 0.4714i
  -0.5000 + 0.2887i
  -0.5000 - 0.2887i
  -0.2500 + 0.4330i
  -0.2500 - 0.4330i

constant value
    0.0556
```

Program 2: Direct Form to Cascade Form Conversion

```
% Direct form to cascade form conversion

clc; clear all; close all;

b = [4 5 6];   % numerator coefficients of direct form
a = [1 2 3];   % denominator coefficients of direct form

% compute gain coefficient
b0 = b(1);
a0 = a(1);

b = b / b0;
a = a / a0;

m = length(b);
n = length(a);

if n > m
    b = [b zeros(1, n - m)];
elseif m > n
    a = [a zeros(1, m - n)];
end

k = floor(n / 2);

B = zeros(k, 3);
A = zeros(k, 3);
```

```
if k * 2 == n
    b = [b 0];
    a = [a 0];
end

broots = cplxpair(roots(b));
aroots = cplxpair(roots(a));

for i = 1 : 2 : 2 * k
    brow = broots(i : i+1, :);
    brow = real(poly(brow));
    B(fix((i+1)/2), :) = brow;

    arow = aroots(i : i+1, :);
    arow = real(poly(arow));
    A(fix((i+1)/2), :) = arow;
end

disp('numerator coefficients of cascade form')
disp(brow)

disp('denominator coefficients of cascade form')
disp(arow)
```

Output:

```
numerator coefficients of cascade form
    1.0000    1.2500    1.5000

denominator coefficients of cascade form
    1.0000    2.0000    3.0000
```

Program 3: Cascade Form Realization of FIR & IIR Filters

```
% Cascade form realization of FIR & IIR filters

clc; clear all; close all;

b = [4 5 6];     % numerator coefficients of direct form
a = [1 2 3];     % denominator coefficients of direct form

% compute gain coefficient
b0 = b(1);

x = [1 2 3 8 9 4 6 7 10];   % input sequence

[k 1] = size(b);
n = length(x);
w = zeros(k+1, n);

w(1, :) = x;

for i = 1:1:k
    w(i+1, :) = filter(b(i, :), a(i, :), w(i, :));
end

y = b0 * w(k+1, :);

disp('output of the final filter operation')
disp(y)
```

Output:

```
output of the final filter operation
    16    20    24   128    48   -44   336  -212  -140
```

Result:

- Parallel form realization of the IIR filter was obtained successfully.
- Direct form filter was converted into cascade form correctly.
- FIR and IIR filters were implemented using cascade structure and the output was observed.

Conclusion:

This experiment demonstrated different realization structures of digital filters including parallel and cascade forms. These structures improve numerical stability and are commonly used in practical DSP applications.