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Programming with Nonequispaced FFT

Solution 3 **C Library Hands On**

Exercise 2:
The file `simple_test` initialises a plan for a three-dimensional forward FFT with $n_0 \times n_1 \times n_2 = 2 \times 2 \times 4$ Fourier coefficients. Random Fourier coefficients $\hat{g}_{k_0 k_1 k_2} \in \mathbb{C}^3$, $k_0 = 0, 1$, $k_1 = 0, 1$, $k_2 = 0, \ldots, 3$ are generated corresponding to their parallel distribution. Input and output of the forward FFT are displayed. We see that distribution of input and output data differs. Also, the backward transform is executed, showing that the FFT is a unitary transform.

```
Rank 0: PFFT, g_hat(2,2:2,1:4):
   0. 2.50e+02+-2.50e+02i, 1.25e+02+-1.25e+02i, 8.33e+01+-8.33e+01i, 6.25e+01+-6.25e+01i,

Rank 1: PFFT, g_hat(2,1:1,1:4):
   0. 5.00e+02+-5.00e+02i, 1.67e+02+-1.67e+02i, 1.00e+02+-1.00e+02i, 7.14e+01+-7.14e+01i,

Rank 2: PFFT, g_hat(1,1:1,1:4):
   0. 1.00e+03+-1.00e+03i, 2.00e+02+-2.00e+02i, 1.11e+02+-1.11e+02i, 7.69e+01+-7.69e+01i,

Rank 3: PFFT, g_hat(1,2:2,1:4):
   0. 3.33e+02+-3.33e+02i, 1.43e+02+-1.43e+02i, 9.09e+01+-9.09e+01i, 6.67e+01+-6.67e+01i,

Rank 0: PFFT, g(3,2:2,1:2):
   0. 8.36e+02+-8.36e+02i, 4.03e+02+-4.03e+02i,
PFFT, g(4,2:2,1:2):
   0. 9.59e+02+-8.00e+02i, 4.27e+02+-3.99e+02i,

Rank 1: PFFT, g(1,2:2,1:2):
   0. 1.07e+03+-1.07e+03i, 4.37e+02+-4.37e+02i,
PFFT, g(2,2:2,1:2):
   0. 8.00e+02+-9.59e+02i, 3.99e+02+-4.27e+02i,

Rank 2: PFFT, g(1,1:1,1:2):
   0. 3.38e+03+-3.38e+03i, 6.63e+02+-6.63e+02i,
PFFT, g(2,1:1,1:2):
   0. 1.34e+03+-2.05e+03i, 5.23e+02+-6.06e+02i,

Rank 3: PFFT, g(3,1:1,1:2):
   0. 1.56e+03+-1.56e+03i, 5.41e+02+-5.41e+02i,
PFFT, g(4,1:1,1:2):
   0. 2.05e+03+-1.34e+03i, 6.06e+02+-5.23e+02i,

Rank 0: PFFT^H, g_hat(2,2:2,1:4):
   0. 2.50e+02+-2.50e+02i, 1.25e+02+-1.25e+02i, 8.33e+01+-8.33e+01i, 6.25e+01+-6.25e+01i,

Rank 1: PFFT^H, g_hat(2,1:1,1:4):
   0. 5.00e+02+-5.00e+02i, 1.67e+02+-1.67e+02i, 1.00e+02+-1.00e+02i, 7.14e+01+-7.14e+01i,

Rank 2: PFFT^H, g_hat(1,1:1,1:4):
   0. 1.00e+03+-1.00e+03i, 2.00e+02+-2.00e+02i, 1.11e+02+-1.11e+02i, 7.69e+01+-7.69e+01i,

Rank 3: PFFT^H, g_hat(1,2:2,1:4):
   0. 3.33e+02+-3.33e+02i, 1.43e+02+-1.43e+02i, 9.09e+01+-9.09e+01i, 6.67e+01+-6.67e+01i,
```

For time measurement add some lines like

```
double start, stop;

start = MPI_Wtime();
pfft_execute(fftplan_forw);
stop = MPI_Wtime();
printf("Forward FFT takes %.2e seconds.\n", stop - start);

start = MPI_Wtime();
pfft_execute(fftplan_back);
stop = MPI_Wtime();
printf("Backward FFT takes %.2e seconds.\n", stop - start);
```

Exercise 3:
The file `simple_test` initialises a plan for a three-dimensional parallel NFFT with $N_0 \times N_1 \times N_2 = 2 \times 2 \times 4$ Fourier coefficients and $M = 4$ nodes. Random Fourier coefficients $\hat{f}_{k_0 k_1 k_2} \in \mathbb{C}^3$, $k_0 = 0, 1$, $k_1 = 0, 1$, $k_2 = 0, \ldots, 3$ and random nodes $\mathbf{x}_j \in [0, 1)^3$, $j = 0, \ldots, 3$ are generated corresponding to their parallel distribution. Input and output of the NFFT are displayed. Also, the adjoint transform is executed, showing that the NFFT is, in contrast to the FFT, a non-unitary transform.

```
Rank 0: PNFFT, f_hat(2,2:2,1:4):
   0. 2.50e+02+-2.50e+02i, 1.25e+02+-1.25e+02i, 8.33e+01+-8.33e+01i, 6.25e+01+-6.25e+01i,

Rank 1: PNFFT, f_hat(2,1:1,1:4):
   0. 5.00e+02+-5.00e+02i, 1.67e+02+-1.67e+02i, 1.00e+02+-1.00e+02i, 7.14e+01+-7.14e+01i,

Rank 2: PNFFT, f_hat(1,1:1,1:4):
   0. 1.00e+03+-1.00e+03i, 2.00e+02+-2.00e+02i, 1.11e+02+-1.11e+02i, 7.69e+01+-7.69e+01i,

Rank 3: PNFFT, f_hat(1,2:2,1:4):
   0. 3.33e+02+-3.33e+02i, 1.43e+02+-1.43e+02i, 9.09e+01+-9.09e+01i, 6.67e+01+-6.67e+01i,

Rank 0, PNFFT, x
   0. 5.416120e-01, 6.084475e-01, 6.581622e-01,

Rank 1, PNFFT, x
   0. 2.771081e-02, 8.481704e-01, 1.562395e-01,

Rank 2, PNFFT, x
   0. 0.000000e+00, 3.275857e-01, 1.524094e-01,

Rank 3, PNFFT, x
   0. 5.138707e-01, 8.786279e-02, 6.543168e-01,

Rank 0, PNFFT, f
   0. 3.37e+02+-5.51e+02i,

Rank 1, PNFFT, f
   0. 1.78e+03+-2.62e+03i,

Rank 2, PNFFT, f
   0. 1.99e+03+-6.66e+02i,

Rank 3, PNFFT, f
   0. 6.08e+02+-4.99e+02i,
```

```
Rank 0: PNFFT^H, f_hat(2,2:2,1:4):
   0. -1.08e+03+-1.02e+03i, -1.35e+03+1.30e+02i, 1.37e+03+-4.39e+02i, 4.86e+02+-1.15e+03i,

Rank 1: PNFFT^H, f_hat(2,1:1,1:4):
   0. 3.03e+03+-2.02e+03i, -2.44e+02+-6.55e+03i, 8.65e+02+3.75e+03i, 6.17e+03+2.32e+03i,

Rank 2: PNFFT^H, f_hat(1,1:1,1:4):
   0. 4.66e+03+-4.28e+03i, -2.91e+02+-3.59e+03i, 2.40e+03+6.17e+03i, 3.46e+03+1.12e+03i,

Rank 3: PNFFT^H, f_hat(1,2:2,1:4):
   0. -1.29e+03+-7.25e+02i, -1.83e+03+8.34e+02i, 1.32e+03+-7.48e+02i, -2.26e+01+-1.81e+03i,
```

For time measurement add some lines like

```
double start, stop;

start = MPI_Wtime();
pnfft_trafo(&nfft);
stop = MPI_Wtime();
printf("Forward FFT takes %.2e seconds.\n", stop - start);

start = MPI_Wtime();
pnfft_adj(&nfft);
stop = MPI_Wtime();
printf("Backward FFT takes %.2e seconds.\n", stop - start);
```