# M4 DSP Matrix Functions

NuMicro® 32 位系列微控制器範例代碼介紹

## 文件資訊

| | |
|---|---|
| 代碼簡述 | 本範例代碼使用M4內核DSP計算矩陣運算 |
| BSP 版本 | M480 Series BSP CMSIS V3.04.000 |
| 開發平台 | NuMaker-PFM-M487 Ver 3.0 |

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# 1 功能介紹

## 1.1 簡介

CMSIS DSP函式庫有許多關於矩陣的運算包含：

1. 矩陣加法運算
2. 矩陣減法運算
3. 矩陣乘法運算
4. 逆矩陣
5. 矩陣縮放
6. 轉置矩陣

在此範例程式使用CMSIS DSP函式庫進行轉置矩陣、矩陣乘法和反矩陣運算，用戶可以直接使用這些函式，來實現自己的數學方程式運算。程式內比較了有無使用DSP計算時間的差異，並計算效率提升比率。

## 1.2 原理

使用者須先用arm_matrix_instance_f32宣告矩陣變數，再來呼叫函式arm_mat_init_f32()對使用到的矩陣初始化設定，定義矩陣直行與橫列個數以及矩陣數值。完成設定後即可對各矩陣進行運算，其程式設定如下表。

| arm_mat_init_f32(arm_matrix_instance_f32 *S, uint16_t nRows, uint16_t nColumns, float32_t *pData) | | |
|---|---|---|
| **參數：** | *S | [in, out] 指向所宣告的浮點數矩陣結構 |
| | nRows | [in] 矩陣直行個數 |
| | nColumns | [in] 矩陣橫列個數 |
| | *pData | [in] 矩陣數據 |
| **回傳值：** | | 無 |

| arm_mat_add_f32(const arm_matrix_instance_f32 *pSrcA, const arm_matrix_instance_f32 *pSrcB, arm_matrix_instance_f32 *pDst) | | |
|---|---|---|
| **參數：** | *pSrcA | [in] 輸入被加數矩陣 |
| | *pSrcB | [in] 輸入加數矩陣 |
| | *pDst | [out] 輸出結果矩陣 |

| | |
|---|---|
| 回傳值： | 成功顯示ARM_MATH_SUCCESS, 矩陣不相合則顯示 ARM_MATH_SIZE_MISMATCH |

| arm_mat_sub_f32(const arm_matrix_instance_f32 *pSrcA, const arm_matrix_instance_f32 *pSrcB, arm_matrix_instance_f32 *pDst) | | |
|---|---|---|
| 參數： | *pSrcA | [in] 輸入被減數矩陣 |
| | *pSrcB | [in] 輸入減數矩陣 |
| | *pDst | [out] 輸出結果矩陣 |
| 回傳值： | | 成功顯示ARM_MATH_SUCCESS, 矩陣不相合則顯示 ARM_MATH_SIZE_MISMATCH |

| arm_mat_mult_f32(const arm_matrix_instance_f32 *pSrcA, const arm_matrix_instance_f32 *pSrcB, arm_matrix_instance_f32 *pDst) | | |
|---|---|---|
| 參數： | *pSrcA | [in] 輸入被乘數矩陣 |
| | *pSrcB | [in] 輸入乘數矩陣 |
| | *pDst | [out] 輸出結果矩陣 |
| 回傳值： | | 成功顯示ARM_MATH_SUCCESS, 矩陣不相合則顯示 ARM_MATH_SIZE_MISMATCH |

| arm_mat_inverse_f32(const arm_matrix_instance_f32 *pSrc, arm_matrix_instance_f32 *pDst) | | |
|---|---|---|
| 參數： | *pSrc | [in] 輸入欲計算矩陣 |
| | *pDst | [out] 輸出逆矩陣 |
| 回傳值： | | 成功顯示ARM_MATH_SUCCESS, 矩陣不為方陣則顯示ARM_MATH_SIZE_MISMATCH, 若矩陣不可逆顯示ARM_MATH_SINGULAR |

| arm_mat_scale_f32(const arm_matrix_instance_f32 *pSrc, float32_t scale, arm_matrix_instance_f32 *pDst) | | |
|---|---|---|
| 參數： | *pSrc | [in] 輸入欲計算矩陣 |
| | scale | [in] 縮放參數 |
| | *pDst | [out] 輸出結果矩陣 |
| 回傳值： | | 成功顯示ARM_MATH_SUCCESS |

| arm_mat_trans_f32(const arm_matrix_instance_f32 *pSrc, arm_matrix_instance_f32 *pDst) | | |
|---|---|---|
| 參數： | *pSrc | [in] 輸入欲計算矩陣 |
| | *pDst | [out] 輸出轉置後矩陣 |
| 回傳值： | | 成功顯示ARM_MATH_SUCCESS |

## 1.3 執行結果

執行後會打印出以下資訊

```
+----------------------------------------+
|     DSP Matrix functions Sample Code   |
+----------------------------------------+

Calculating time with DSP instruction is 0.040667 ms

Calculating time without DSP instruction is 0.243083 ms

Efficiency increase rate is 5.98
```

# 2 代碼介紹

使用CMSIS DSP函數庫進行轉置矩陣、矩陣乘法和反矩陣運算：

```
/* Initialize A Matrix Instance with numRows, numCols and data array(A_f32) */
arm_mat_init_f32(&A, numRows, numCols, A_f32);

/* Initialize Matrix Instance AT with numRows, numCols and data array(AT_f32) */
arm_mat_init_f32(&AT, numRows, numCols, AT_f32);

/* calculation of A transpose with DSP instruction */
arm_mat_trans_f32(&A, &AT);

/* Initialize ATMA Matrix Instance with numRows, numCols and data array(ATMA_f32) */
arm_mat_init_f32(&ATMA, numRows, numCols, ATMA_f32);

/* calculation of AT Multiply with A with DSP instruction */
arm_mat_mult_f32(&AT, &A, &ATMA);

/* Initialize ATMAI Matrix Instance with numRows, numCols and data array(ATMAI_f32) */
arm_mat_init_f32(&ATMAI, numRows, numCols, ATMAI_f32);

/* calculation of Inverse ((Transpose(A) * A) with DSP instruction */
arm_mat_inverse_f32(&A, &ATMAI);
```

接著使用CPU進行相同的計算：

```
/* Matrix Inverse (number of rows) */
void MatrixInverse(int n)
{
    uint32_t i,j,k;
    double t;
    for(i=0; i<n; ++i) {
        for(j=0; j<n; ++j) {
            A1_f32[i][n+j] = 0;
        }
    }
    for(i=0; i<n; ++i) {
        A1_f32[i][n+i] = 1;
    }
    for(i=0; i<n; ++i) {
```

```
        if(A1_f32[i][i] == 0)
            for(j=i+1; j<n; ++j)
                if(A1_f32[j][i] != 0) {
                    for(k=i; k<n*2; ++k)
                        swap(&A1_f32[i][k], &A1_f32[j][k]);
                    break;
                }
        /* if Matrix inverse not exist*/
        if(A1_f32[i][i] == 0) break;

        t = A1_f32[i][i];
        for(k=i; k<n*2; ++k) {
            A1_f32[i][k] /= t;
        }
        for(j=0; j<n; ++j) {
            if(i != j && A1_f32[j][i] != 0) {
                double t = A1_f32[j][i];
                for(k=i; k<n*2; ++k) {
                    A1_f32[j][k] -= A1_f32[i][k] * t;
                }
            }
        }
    }
}
/* Matrix Transpose (number of rows, number of columns) */
void MatrixTranspose(int m, int n)
{
    uint32_t i, j;
    for(i=0; i<n; i++) {
        for(j=0; j<m; j++) {
            resultT[i][j] = A1_f32[j][i];
        }
    }
}
/* Matrix Multiplication (number of rows, number of columns) */
void MatrixMult(int m, int n, int p)
{
    uint32_t i, j, k;
    for(i=0; i<m; i++) {
        for(j=0; j<p; j++) {
            resultM[i][j] = 0;
```

```
            for(k=0; k<n; k++) {
                resultM[i][j] = resultM[i][j] + resultT[i][k] * A1_f32[k][j];
            }
        }
    }
}
```

把計數器換成時間，其中計數器時鐘源為HXT 12MHz：

```
/* Calculate the time, timer clock source is 12M, unit is ms */
DSPCalTime = (DSPCalTime/12000000) * 1000;
CalTime = (CalTime/12000000)* 1000;
```

# 3 軟體與硬體環境

## ● 軟體環境

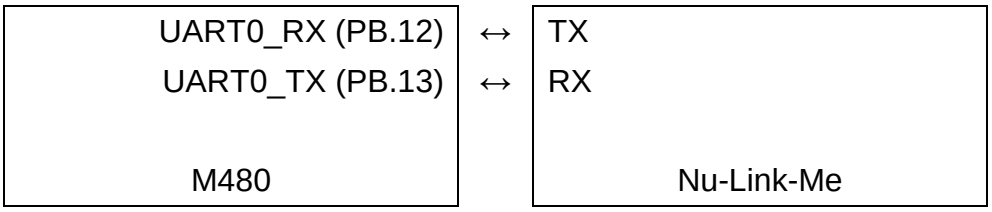
- ■ BSP 版本
  - ◆ M480 Series BSP CMSIS V3.04.000
- ■ IDE 版本
  - ◆ Keil uVersion 5.26

## ● 硬體環境

- ■ 電路元件
  - ◆ NuMaker-PFM-M487 or other M480 Development Board
- ■ 示意圖

M480 的 UART0_RX(PB.12)、UART0_TX(PB.13)連接至 Nu-Link Me，打印訊息。

設置終端機的 COM Port 與 Baud，COM Port 的編號可在裝置管理員中找到「NuBridge Virtual Com Port (COMX)」，Baud 設置為 115200。



# 4 目錄資訊

- EC_M480_DSP_Matrix_V1.00
  - Library — Sample code header and source files
    - CMSIS — Cortex® Microcontroller Software Interface Standard (CMSIS) by Arm® Corp.
    - Device — CMSIS compliant device header file
    - StdDriver — All peripheral driver header and source files
  - SampleCode
    - ExampleCode — Source file of example code

# 5 如何執行範例程式

1. 根據目錄資訊章節進入 ExampleCode 路徑中的 KEIL 資料夾，雙擊 DSP_Matrix.uvproj
2. 進入編譯模式介面
   a. 編譯
   b. 下載代碼至記憶體
   c. 進入 / 離開除錯模式
3. 進入除錯模式介面
   a. 執行代碼

# 6 修訂紀錄

| Date | Revision | Description |
|---|---|---|
| Jun. 25, 2019 | 1.00 | 1. 初始發布. |

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