- example 1

(1) LER

$$\sum_i^{1..M} \sum_j^{1..m} \sum_k^{1..n} \sum_l^{1..n} x[i,l] \cdot y[l,j] \cdot s[j,k] \Rightarrow r[i,k]$$

(2) LER optimized formula

$$\sum_l^{1..n} \sum_k^{1..n} \sum_j^{1..m} y[l,j] \cdot s[j,k] \Rightarrow temp[l,k]$$

$$\sum_i^{1..m} \sum_k^{1..n} \sum_l^{1..n} x[i,l] \cdot temp[l,k] \Rightarrow r[i,k]$$

- example 2

(1) LER

$$\forall t \sum_i^{0..m} a[i] + b[i] \cdot w_t \Rightarrow d_t$$

(2) LER optimized formulae

$$\sum_i^{0..m} a[i] \Rightarrow A$$

$$\sum_i^{0..m} b[i] \Rightarrow B$$

$$\forall t \; A + B \cdot w_t \Rightarrow d_t$$

- Ssymm

(1) LER

$$\sum_i^{0..N} \sum_j^{0..M} \sum_k^{0..j-1} a[j,k] \cdot b[i,j] \Rightarrow c[i,k]$$

$$\sum_{i}^{0,N} \sum_{j}^{0,N} \sum_{k}^{0,j-1} a[j,j] \cdot b[i,j] \Rightarrow c[i,j]_j$$

(2) LER optimization

$$\sum_{i}^{0,N} \sum_{j}^{0,N} j \cdot a[j,j] \cdot b[i,j] \Rightarrow c[i,j]$$

- fmri

(1) LER

$$\sum_{i}^{0,N} \sum_{j}^{0,i} b[i] \cdot c[j] \Rightarrow a[i]$$

(2) LER opt

$$\sum_{i}^{0,N} \sum_{j}^{0,i} c[j] \Rightarrow temp2[i]$$

$$\sum_{i}^{N} b[i] \cdot temp2[i] \Rightarrow a[i]$$

$$\Downarrow$$

$$\sum_{i}^{N} b[i] \; (incl[i]: incl[i-1] + c[i] \rightarrow incl[0] = y[0]) \Rightarrow a[i]$$

- fuse

(1) LER

$$\sum_{i}^{N} \sum_{j}^{N} a[i] + b[j] \Rightarrow a[i]$$

(2) LER opt

$$\sum_{j}^{N} b[j] \Rightarrow temp$$

$$\sum_{i}^{N} \lambda \cdot a\{i\} + temp \Rightarrow a\{i\}$$

- pde

$$\sum_{k}^{z_{n-1}} \sum_{j}^{y_{n-1}} \sum_{i}^{x_{n-1}} \sum_{m}^{0,6} c\{m\} * x\{i\} + c\{m\} * y\{j\} + c\{m\} * z\{k\}$$
$$+ c\{m\} * x'\{i\} + c\{m\} * y'\{j\} + c\{m\} * z'\{k\}$$
$$+ c\{m\} * x''\{i\} + c\{m\} * y''\{j\} + c\{m\} * z''\{k\}$$
$$+ c\{m\} * x'''\{i\} + c\{m\} * y'''\{j\} + c\{m\} * x\{i\} * y\{j\} * z\{k\}$$
$$\Rightarrow d\{m,i\}$$

(2) LER opt

$$\sum_{i}^{x_{n-1}} \sum_{m}^{0,6} c\{m\} * x\{i\} \Rightarrow temp1\{m,i\}$$

$$\sum_{i}^{x_{n-1}} \sum_{m}^{0,6} temp1\{m,i\} * x\{i\} \Rightarrow temp2\{m,i\}$$

$$\sum_{i}^{x_{n-1}} \sum_{m}^{0,6} temp2 * x\{i\} \Rightarrow temp3\{m,i\}$$

$$\sum_{j}^{y_{n-1}} y\{j\} \Rightarrow temp4\{j\}$$

$$\sum_{j}^{y_{n-1}} temp4\{j\} * y\{j\} \Rightarrow temp5\{j\}$$

$$\sum_{j}^{y_{n-1}} temp5\{j\} * y\{j\} * y\{j\} \Rightarrow temp6\{j\}$$

$$\sum_{k}^{z_{n-1}} \sum_{j}^{y_{n-1}} \sum_{i}^{x_{n-1}} \sum_{m}^{0,6} temp1\{m,i\} + c\{m\} * temp4\{j\} + c\{-1\} * z\{k\}$$
$$+ temp2\{m,i\} + c\{m\} * temp5\{j\} + c\{-1\} * z'\{k\}$$
$$+ temp3\{m,i\} + c\{m\} * temp6\{j\} + c\{-1\} * z''\{k\}$$
$$+ temp7\{m,i\} + c\{m\} * temp8\{j\} + temp9\{m,j\} * temp4\{j\}$$

- priv2

(1) $\sum_{i}^{N} \sum_{j}^{N} \sum_{k}^{N} a\{i,j\} * a\{i,j\} \Rightarrow dist_j$

$\sum_{i}^{N} \sum_{j}^{N} \sum_{k}^{N} a\{i,j\} + a\{i,j\} \Rightarrow dist1_j$

(2) LER opt

$N \cdot \sum_{i}^{N} \sum_{j}^{N} a\{i,j\} * a\{i,j\} \Rightarrow dist$

$2N \sum_{i}^{N} \sum_{j}^{N} a\{i,j\} \Rightarrow dist1$

- bgd

(1) $\sum_{i}^{M} \sum_{j}^{D} x\{i,j\} * w\{j\} \Rightarrow s$

$\sum_{i}^{M} \sum_{j}^{D} s \cdot x\{i,j\} \Rightarrow d\{j\}$

- ccsd_multisize

$\sum_{a}^{0,N} \sum_{b}^{0,V} \sum_{c}^{0,V} \sum_{i}^{0,V} \sum_{j}^{0,V} \sum_{x}^{0,V} \sum_{e}^{0,V} \sum_{m}^{0,1000} T_2\{c,e,i,j\} * O2\{a,b,e,k\} \Rightarrow X\{a,b,c,i,j,k\}$

opt:

$1000 \sum_{a}^{0,N} \sum_{b}^{0,V} \sum_{c}^{0,V} \sum_{i}^{0,V} \sum_{j}^{0,V} \sum_{x}^{0,V} \sum_{e}^{0,V} T_2\{c,e,i,j\} * O2\{a,b,e,k\} \Rightarrow X\{a,b,c,i,j,k\}$

- ccsd_onesize

$$\sum_{a}^{0,V}\sum_{b}^{0,V}\sum_{c}^{0,V}\sum_{i}^{0,O}\sum_{j}^{0,O}\sum_{x}^{0,O}\sum_{e}^{0,V}\sum_{m}^{0,O} T_2(a,b,k,m) * D1(c,m,i,j) + T_2(c,e,i,j) * D_2(a,b,e,k)$$

$$\Rightarrow X(a,b,c,i,j,k)$$

Opt:

$$\sum_{a}^{0,V}\sum_{b}^{0,V}\sum_{c}^{0,V}\sum_{i}^{0,O}\sum_{j}^{0,O}\sum_{x}^{0,O}\sum_{m}^{0,O} T_2(a,b,k,m) * D1(c,m,i,j) \cdot V$$

$$+ \sum_{a}^{0,V}\sum_{b}^{0,V}\sum_{c}^{0,V}\sum_{i}^{0,O}\sum_{j}^{0,O}\sum_{x}^{0,O}\sum_{e}^{0,V} T_2(c,e,i,j) * D_2(a,b,e,k) \cdot O$$

$$\Rightarrow X(a,b,c,i,j,k)$$

Time Comparsion

org: the original code

opt: the optimized code

	o0 org	o3 org	o0 opt	o3 opt
example1	0.361959s	0.343943s	0.014369s	0.013021s
example2	0.358597s	0.372946s	0.001503s	0.000934s
ssymm	0.194085s	0.194749s	0.105189s	0.102416s
fmri	0.199585s	0.203415s	0.000782s	0.001460s
fuse	0.717086s	0.710207s	0.001233s	0.001873s
pde	0.877304s	0.885199s	0.860953s	0.868149s
priv2	3.475780s	3.481572s	0.005383s	0.002886s
ccsd_onesize	89.396114s	90.269578s	7.748550s	7.537037s
ccsd_multisize	34.441253s	34.467335s	0.048842s	0.048656s

The optimized code for each program is attached in the same folder.