## Re: QRD and QRI to solve LLS problem with oneMKL LAPACK gels or gelsy?

hm3_KL <hm3_KL@student.wou.edu.my>

Mon 16/05/2022 16:40

To: Intel Customer Support <supportreplies@intel.com>

Dear Aik Eu,

I fully agree with one of your respective team member recommendation to use the existing QRD from FPGA code samples especially this project continues to make use of Direct Programming DPC++FPGA and that is my main objective.

As I am just a beginner in using FPGA, there are many areas not well understood and much to learn. Appreciate your team member(s) to enlighten me on the followings:

1) The TEM data in USF format are attached. The attached zip file consists of 3 sets of data (K004 to K006) both in raw.usf and stcked.usf formats were taken from TEM Instrument and already converted to raw and stack data in USF formats.

2) Presume these USF data can be converted/read/imported directly into QRD of the FPGA code sample? Please provide example or sample code for me to convert/read/import in to QRD. By doing so am I able to get the $A$-matrix and $y$-vector in order for me to implement 1. perform QRD on $A$-matrix to generate $Q, R$ using the library in code samples, kindly advise the name of the code sample in the library.

3) After successfully implemented above steps, I then continue to implement 2.Calculate $q = Q^T y$ using matrix-vector product (this is very trivial) and 3. Back-substitute to solve $R_1 c = q_1$(this is also very trivial).

Thank you very much for your help.

Best Regards
Hoe Min

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**From:** Intel Customer Support <supportreplies@intel.com>
**Sent:** 10 May 2022 09:32
**To:** hm3_KL <hm3_KL@student.wou.edu.my>
**Subject:** QRD and QRI to solve LLS problem with oneMKL LAPACK gels or gelsy?

Hi hoemin,

I obtained the following info as below:
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According to one of the repective team member, It is much better performance by using the existing QRD from the FPGA code samples than by trying to use the MKL libraries which are not optimized for FPGA.

Linear Least Squares is used to solve coefficients $c_1$, $c_2$, $c_3$, … $c_n$for a system of linear equations when you know $f_1(x)$, $f_2(x)$, $f_3(x)$…$f_n(x)$ and have measured ordered pairs $(x_1,y_1)$, $(x_2,y_2)$, $(x_3,y_3)$… $(x_m,y_m)$.

$$c_1 * f_1(x_1) + c_2 * f_2(x_1) + c_3 * f_2(x_1) + \cdots + c_n * f_n(x_1) = y_1$$
$$c_1 * f_1(x_2) + c_2 * f_2(x_2) + c_3 * f_2(x_2) + \cdots + c_n * f_n(x_2) = y_2$$
$$c_1 * f_1(x_3) + c_2 * f_2(x_3) + c_3 * f_2(x_3) + \cdots + c_n * f_n(x_3) = y_3$$
…
$$c_1 * f_1(x_m) + c_2 * f_2(x_m) + c_3 * f_2(x_m) + \cdots + c_n * f_n(x_m) = y_m$$

You can model this as a matrix equation like this:
$A \cdot c = y$

$$\begin{matrix} f_1(x_1) & f_2(x_1) & f_3(x_1) & f_n(x_1) \\ f_1(x_2) & f_2(x_2) & f_3(x_2) & f_n(x_2) \\ f_1(x_3) & f_2(x_3) & f_3(x_3) & f_n(x_3) \\ f_1(x_m) & f_2(x_m) & f_3(x_m) & f_n(x_m) \end{matrix}$$

Where $A$is a matrix, $c$is a vector $c_1$, $c_2$, $c_3$, … $c_n$and $y$is a vector $y_1, y_2, y_3, \cdots, y_m$.

If you factor $A$with QRD, you get $QR \cdot c = y$, and can find $Rc = Q^T y$. Since $A$is rectangular ($m > n$), the resulting $R$- matrix will be made of an $n \times n$ upper-triangular matrix $R_1$, and a $(m-n) \times n$matrix of 0s. then we can split the vector $q = Q^T y$into an n-element vector $q_1$and an $(m-n)$element vector $q_2$:

$$\begin{matrix} R_1 \\ 0 \end{matrix} \cdot c = \begin{matrix} q_1 \\ q_2 \end{matrix}$$

We can find a solution for $c$by solving $R_1 c = y_1$; we can solve for $c$using back-substitution since $R_1$is upper-triangular.

Therefore, to implement a LLS given an existing QRD when the $A$-matrix and $y$-vector are known, I think you will need to

1. Perform QRD on $A$-matrix to generate $Q, R$using the library in code samples
2. Calculate $q = Q^T y$ using matrix-vector product (this is very trivial)

3. Back-substitute to solve $R_1 c = q_1$(this is also very trivial)

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Thanks.
Regards,
Aik Eu

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