人工智慧晶片設計與應用
AI-ON-CHIP FOR MACHINE LEARNING AND INFERENCE

Project 1 - TPU

學號：N26091623

姓名：賓維凡

授課教授：陳中和

一、 實現方式

控制器利用計數器的方式實現，控制下列動作：

(1) 計算完成時發出 interrupt 使 pe 清零。

(2) 計算完成時將 pe unit 計算好的結果輸出，若未完成 pe unit 的輸出保持零。

(3) 控制資料從 gbuff 到 pe unit 運算前的資料流動。
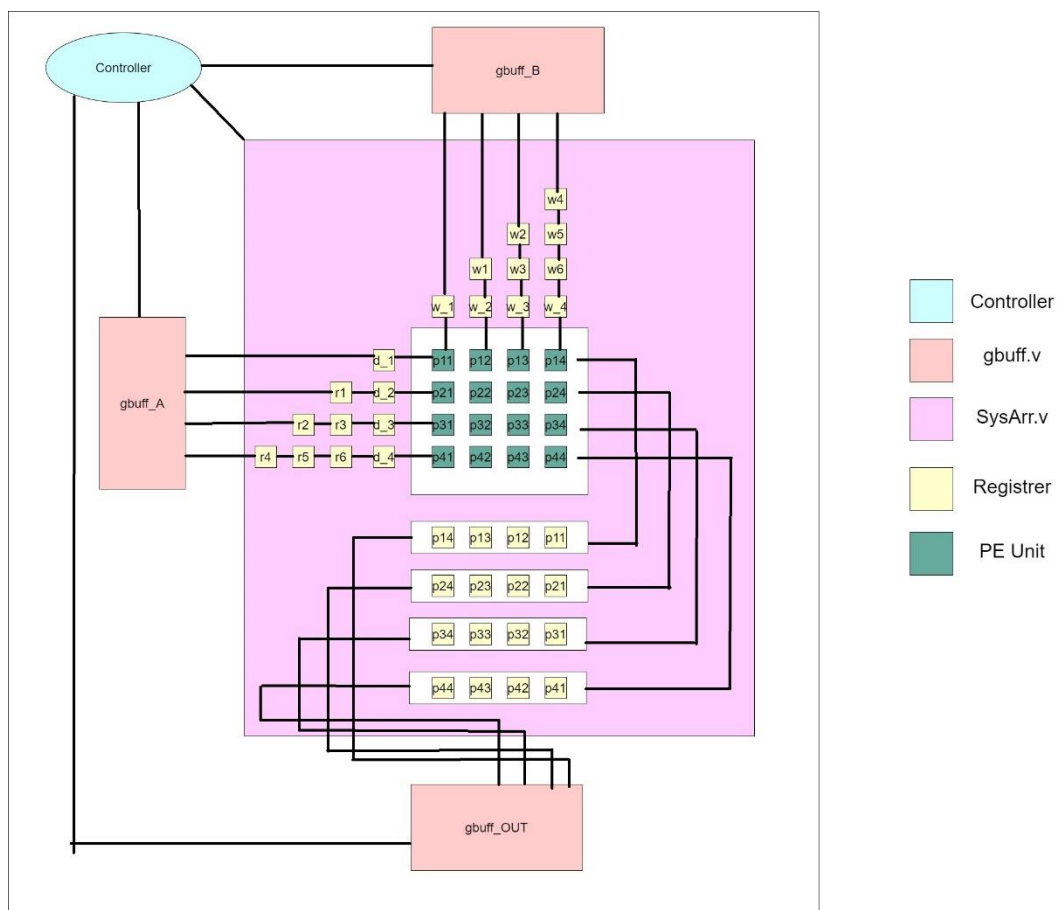
(4) 控制 gbuff_A、gbuff_B、gbuff_OUT 於正確時間讀入或輸出正確 index 的資料。
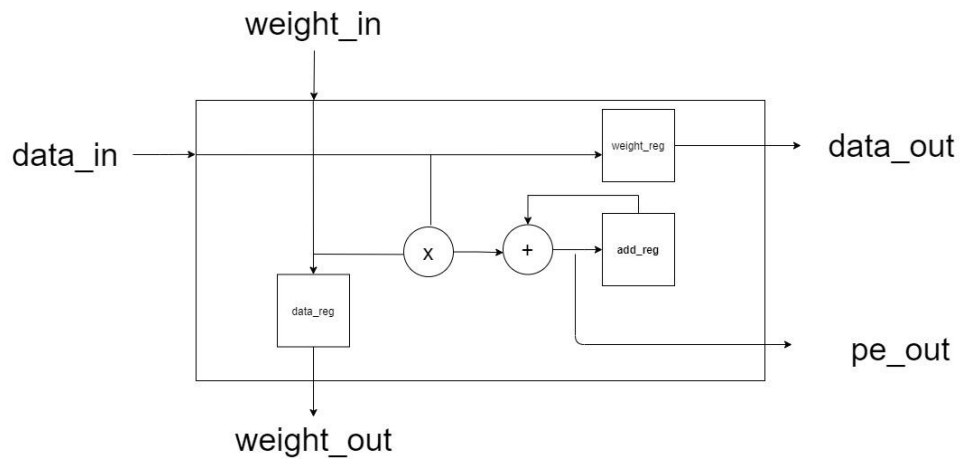

Fig. BIG MAP

二、 程式概述

1. PE Unit 設計：pe.v

weight_in

data_in → weight_reg → data_out

x → + → add_reg

data_reg

pe_out

weight_out

Fig. pe unit design

2. Systolic Array 設計：SysArr.v

(1) 將 pe unit 串接為 4x4 的運算陣列。

(2) 控制器寫在裡面，用於實現脈動陣列的所有功能。

三、 Dataflow

1. 簡述：

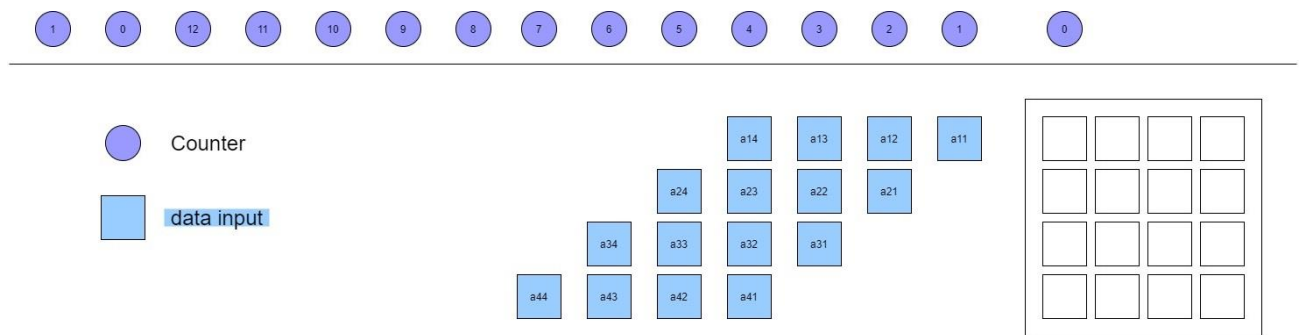針對 k<=4 和 k=9 這兩種不同長度的 dataflow，調整 Counter
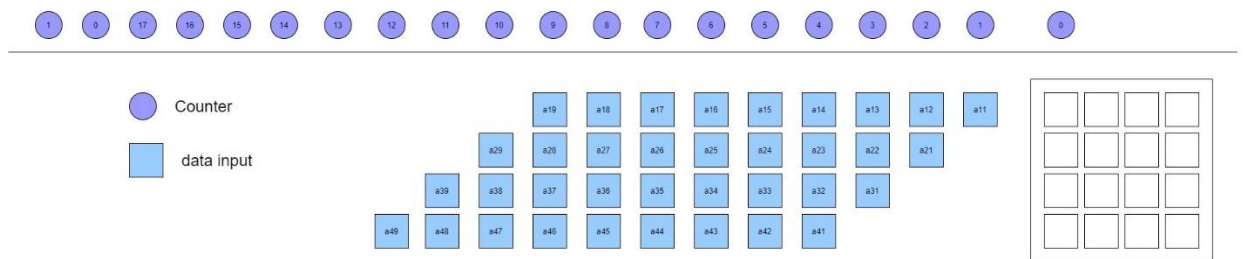
的計數動作來驅動電路輸出正確結果。

Fig. k<=4 的 dataflow

Fig. k=9 的 dataflow

2. 資料流入 Systolic Array 運算前的 delay 實現：

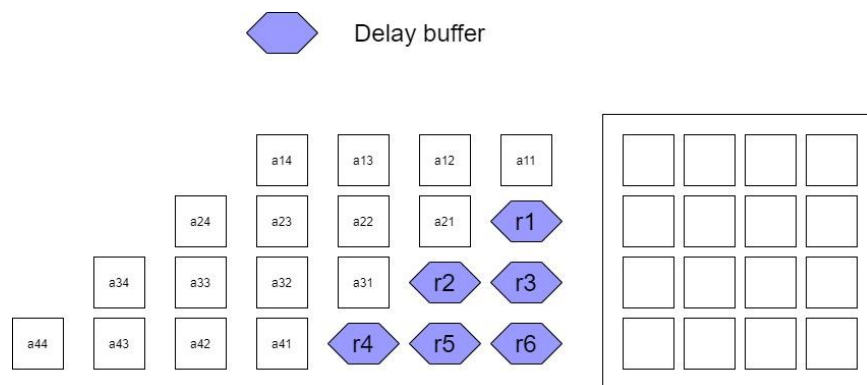準備 12 個暫存器(data、weight 各 6 個)讓需要 delay 的輸入經

過已達到 delay 的目的。

Fig. delay buffer (僅列出 data 輸入要經過的 buffer)

四、 結果

通過 Test1、Test2、Test3 之結果：

(1) Test：

```
# GBUFF_OUT[ 0][ 7: 0] = 07, pass!
# GBUFF_OUT[ 0][15: 8] = 0d, pass!
# GBUFF_OUT[ 0][23:16] = 00, pass!
# GBUFF_OUT[ 0]31:24] = 00, pass!
# GBUFF_OUT[ 1][ 7: 0] = 13, pass!
# GBUFF_OUT[ 1][15: 8] = 1b, pass!
# GBUFF_OUT[ 1][23:16] = 00, pass!
# GBUFF_OUT[ 1]31:24] = 00, pass!
#
#
#                                          / \  //\
#                          |\___/|      /   \//  \\
#                          /0  0  \__  /    //  | \ \
#                         /     /  \/_/    //   |  \  \
#                         @_^_@'/   \/_   //    |   \   \
#                         //_^_/     \/_ //     |    \    \
#                      ( //) |        \///      |     \     \
#                      ( / /) _|_ /   )  //      |      \     _\
#                    ( // /) '/,_ _ _/  ( ; -.    |    _ _\.-~        .-~~~^-.
#    *******************(( / / )) ,-{        _      `-.|.-~-.           .~         `.
#    **                 (( // / ))  '/\      /                 ~-. _ .-~      .-~^-.
#    ** Congratulations! (( /// ))      `.   {            }                  /
#    ** Simulation Passed! (( / ))    .----~-.\        \-'                 .~         `. ^-.
#    **                      **       ///.----..>        \             _ -~             `.  ^-`  ^-_
#    *************************        ///-._ _ _ _ _ _ _}^ - - - - ~                     ~--  ,.-~
#
```

```
# GBUFF_OUT[ 0][ 7: 0] = 07, pass!
# GBUFF_OUT[ 0][15: 8] = 0d, pass!
# GBUFF_OUT[ 0][23:16] = 00, pass!
# GBUFF_OUT[ 0][31:24] = 00, pass!
# GBUFF_OUT[ 1][ 7: 0] = 13, pass!
# GBUFF_OUT[ 1][15: 8] = 1b, pass!
# GBUFF_OUT[ 1][23:16] = 00, pass!
# GBUFF_OUT[ 1][31:24] = 00, pass!
#
#
#                                          / \  //\
#                          |\___/|      /   \//  \\
#                          /0  0  \__  /    //  | \ \
#                         /     /  \/_/    //   |  \  \
#                         @_^_@'/   \/_   //    |   \   \
#                         //_^_/     \/_ //     |    \    \
#                      ( //) |        \///      |     \     \
#                      ( / /) _|_ /   )  //      |      \     _\
#                    ( // /) '/,_ _ _/  ( ; -.    |    _ _\.-~        .-~~~^-.
#    *******************(( / / )) ,-{        _      `-.|.-~-.           .~         `.
#    **                 (( // / ))  '/\      /                 ~-. _ .-~      .-~^-.
#    ** Congratulations! (( /// ))      `.   {            }                  /
#    ** Simulation Passed! (( / ))    .----~-.\        \-'                 .~         `. ^-.
#    **                      **       ///.----..>        \             _ -~             `.  ^-`  ^-_
#    *************************        ///-._ _ _ _ _ _ _}^ - - - - ~                     ~--  ,.-~
#
#
# ** Note: $finish    : C:/Users/a2008/Desktop/top/top_tb.v(177)
#    Time: 5 ms  Iteration: 0  Instance: /top_tb
```

(2) Test2 :

```
# GBUFF_OUT[ 0][ 7: 0] = 04, pass!
# GBUFF_OUT[ 0][15: 8] = 08, pass!
# GBUFF_OUT[ 0][23:16] = 00, pass!
# GBUFF_OUT[ 0]31:24] = 0c, pass!
# GBUFF_OUT[ 1][ 7: 0] = 08, pass!
# GBUFF_OUT[ 1][15: 8] = 10, pass!
# GBUFF_OUT[ 1][23:16] = 00, pass!
# GBUFF_OUT[ 1]31:24] = 18, pass!
# GBUFF_OUT[ 2][ 7: 0] = 0c, pass!
# GBUFF_OUT[ 2][15: 8] = 18, pass!
# GBUFF_OUT[ 2][23:16] = 00, pass!
# GBUFF_OUT[ 2]31:24] = 24, pass!
# GBUFF_OUT[ 3][ 7: 0] = 10, pass!
# GBUFF_OUT[ 3][15: 8] = 20, pass!
# GBUFF_OUT[ 3][23:16] = 00, pass!
# GBUFF_OUT[ 3]31:24] = 30, pass!
#
#
#                                          / \  //\
#                            |\___/|      /   \//  \\
#                           /0  0  \__  /    //  | \ \
#                          /     /  \/_/    //   |  \  \
#                          @_^_@'/   \/_   //    |   \   \
#                          //_^_/     \/_ //     |    \    \
#                       ( //) |        \///      |     \     \
#                     ( / /) _|_ /   ) //        |      \     _\
#                   ( // /) '/,_ _ _/  ( ; -.    |    _ _\.-~        .-~~~^-.
#  *******************(( / / )) ,-{        _      `-.|.-~-.           .~         `.
#  **                (( // / ))  '/\      /                 ~-. _ .-~      .-~^-.
#  **  Congratulations!  (( /// ))      `.   {            }                   /
#  **  Simulation Passed!  (( / ))     .----~-.\        \-'                 .~         `. ^-.
#  **                       **       ///.----..>        \             _ -~             `.  ^-`  ^-_
#  ***************************       ///-._ _ _ _ _ _ _}^ - - - - ~                     ~-- ,.-~
#
# GBUFF_OUT[ 0][ 7: 0] = 04, pass!
# GBUFF_OUT[ 0][15: 8] = 08, pass!
# GBUFF_OUT[ 0][23:16] = 00, pass!
# GBUFF_OUT[ 0][31:24] = 0c, pass!
# GBUFF_OUT[ 1][ 7: 0] = 08, pass!
# GBUFF_OUT[ 1][15: 8] = 10, pass!
# GBUFF_OUT[ 1][23:16] = 00, pass!
# GBUFF_OUT[ 1][31:24] = 18, pass!
# GBUFF_OUT[ 2][ 7: 0] = 0c, pass!
# GBUFF_OUT[ 2][15: 8] = 18, pass!
# GBUFF_OUT[ 2][23:16] = 00, pass!
# GBUFF_OUT[ 2][31:24] = 24, pass!
# GBUFF_OUT[ 3][ 7: 0] = 10, pass!
# GBUFF_OUT[ 3][15: 8] = 20, pass!
# GBUFF_OUT[ 3][23:16] = 00, pass!
# GBUFF_OUT[ 3][31:24] = 30, pass!
#
#
#                                          / \  //\
#                            |\___/|      /   \//  \\
#                           /0  0  \__  /    //  | \ \
#                          /     /  \/_/    //   |  \  \
#                          @_^_@'/   \/_   //    |   \   \
#                          //_^_/     \/_ //     |    \    \
#                       ( //) |        \///      |     \     \
#                     ( / /) _|_ /   ) //        |      \     _\
#                   ( // /) '/,_ _ _/  ( ; -.    |    _ _\.-~        .-~~~^-.
#  *******************(( / / )) ,-{        _      `-.|.-~-.           .~         `.
#  **                (( // / ))  '/\      /                 ~-. _ .-~      .-~^-.
#  **  Congratulations!  (( /// ))      `.   {            }                   /
#  **  Simulation Passed!  (( / ))     .----~-.\        \-'                 .~         `. ^-.
#  **                       **       ///.----..>        \             _ -~             `.  ^-`  ^-_
#  ***************************       ///-._ _ _ _ _ _ _}^ - - - - ~                     ~-- ,.-~
#
#
# ** Note: $finish    : C:/Users/a2008/Desktop/top/top_tb.v(177)
#    Time: 5 ms  Iteration: 0  Instance: /top_tb
```

(3) Test3 :

```
# GBUFF_OUT[ 0][ 7: 0] = 0e, pass!
# GBUFF_OUT[ 0][15: 8] = 0a, pass!
# GBUFF_OUT[ 0][23:16] = 06, pass!
# GBUFF_OUT[ 0]31:24] = 02, pass!
# GBUFF_OUT[ 1][ 7: 0] = 10, pass!
# GBUFF_OUT[ 1][15: 8] = 0e, pass!
# GBUFF_OUT[ 1][23:16] = 08, pass!
# GBUFF_OUT[ 1]31:24] = 01, pass!
# GBUFF_OUT[ 2][ 7: 0] = 18, pass!
# GBUFF_OUT[ 2][15: 8] = 12, pass!
# GBUFF_OUT[ 2][23:16] = 0c, pass!
# GBUFF_OUT[ 2]31:24] = 05, pass!
# GBUFF_OUT[ 3][ 7: 0] = 00, pass!
# GBUFF_OUT[ 3][15: 8] = 00, pass!
# GBUFF_OUT[ 3][23:16] = 00, pass!
# GBUFF_OUT[ 3]31:24] = 00, pass!
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
# ******************((  /  /  ))  ,-{
# **                 (( // / ))  '/\
# **  Congratulations!  (( /// ))
# **  Simulation Passed!  (( / ))
# **                    **
# ****************************
#
```

```
# GBUFF_OUT[ 0][ 7: 0] = 0e, pass!
# GBUFF_OUT[ 0][15: 8] = 0a, pass!
# GBUFF_OUT[ 0][23:16] = 06, pass!
# GBUFF_OUT[ 0][31:24] = 02, pass!
# GBUFF_OUT[ 1][ 7: 0] = 10, pass!
# GBUFF_OUT[ 1][15: 8] = 0e, pass!
# GBUFF_OUT[ 1][23:16] = 08, pass!
# GBUFF_OUT[ 1][31:24] = 01, pass!
# GBUFF_OUT[ 2][ 7: 0] = 18, pass!
# GBUFF_OUT[ 2][15: 8] = 12, pass!
# GBUFF_OUT[ 2][23:16] = 0c, pass!
# GBUFF_OUT[ 2][31:24] = 05, pass!
# GBUFF_OUT[ 3][ 7: 0] = 00, pass!
# GBUFF_OUT[ 3][15: 8] = 00, pass!
# GBUFF_OUT[ 3][23:16] = 00, pass!
# GBUFF_OUT[ 3][31:24] = 00, pass!
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
# ******************((  /  /  ))  ,-{
# **                 (( // / ))  '/\
# **  Congratulations!  (( /// ))
# **  Simulation Passed!  (( / ))
# **                    **
# ****************************
#
#
# ** Note: $finish    : C:/Users/a2008/Desktop/top/top_tb.v(177)
#    Time: 5 ms  Iteration: 0  Instance: /top_tb
```